United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-284

July 1981

Regeneration Outlook on BLM Lands in the Southern Oregon Cascades

William I. Stein

Author

WILLIAM I. STEIN is a principal plant ecologist at the Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, 3200 Jefferson Way, Corvallis, Oregon 97331.

Summary

For more than a decade, various intensities of partial cutting have been used in the southern Oregon Cascades by the Bureau of Land Management, U.S. Department of the Interior, and others to foster establishment of natural regeneration. Difficulties experienced in reforesting some clearcuts were a prime reason for the change to partial cutting. This comprehensive study was cooperatively undertaken to evaluate reforestation results obtained by both clearcutting and partial cutting, to identify influencing variables and problems, and to recommend improvements in silvicultural practices.

Stocking levels, composition of regeneration, and species dominance were determined from data collected on 92 randomly located plots in partial cuts and clearcuts logged during the 1956-70 period in the Dead Indian and Butte Falls areas. Each plot was sampled by twenty 4-milacre (0.00162-hectare) subplots, located systematically in a 2-acre (0.81-hectare) grid. Most partial cuts were moderately or well stocked; clearcuts in the Butte Falls area were also well stocked but many in the Dead Indian area were not.

In partial cuts, regeneration established before logging made up about half the total stocking and dominated nearly half the stocked subplots. Many second-year seedlings were found in partial cuts, few in clearcuts; yet their potential for changing stocking levels is minor. Naturally established true firs, Douglas-fir, and incense-cedar were the dominant species in partial cuts, and artificially established ponderosa pine was dominant in clearcuts. In general, a mix of species was more common in the Butte Falls area than in the Dead Indian—up to six per subplot.

Comparisons of geographic and vegetative characteristics showed that the Dead Indian and Butte Falls areas are more dissimilar than is first evident. Both areas have much gentle terrain and some plateaulike features, but Butte Falls occupies a midslope position west of the Cascade Range summit, whereas Dead Indian mainly occupies upper slopes. An average difference in elevation of 1,400 feet (427 meters) has important implications for length of growing season, frost occurrence, exposure to storm winds, temperature extremes, and other factors. The Butte Falls area appears to average at least 10 inches (25 centimeters) more annual precipitation and has finer, deeper soils with more water-holding capacity. In clearcuts of both areas, about 90 percent of the soil surface appeared to have been disturbed during harvest; in partial cuts, 50 to 60 percent. Canopy averaged about 45 percent in partial cuts, and ground cover 49 percent. In clearcuts, ground cover averaged 61 percent.

In partial cuts, total and subsequent stocking averaged less in the white fir forest type than in the Douglas-fir, Shasta red fir, and pine types; the reverse was true in clearcuts. Stocking did not differ greatly by soil series, but large differences were found among some locations and drainages. Total and subsequent stocking were lowest in the western part of the Dead Indian area which is also where the white fir type is most fully developed.

Stocking correlated significantly with an array of environmental variables. The associations differed for partial cuts and clearcuts, Butte Falls and Dead Indian areas, forest types, and for classes and species of regeneration. For partials cuts, associations based on data grouped by forest types were judged strongest and most useful; associations for clearcuts were about equally strong whether based on forest type or geographic area. In both partial cuts and clearcuts, stocking generally increased as amount of woody perennials increased, and tended to be less as total ground cover, grass, radiation index, and elevation increased. Regression equations describe present stocking patterns, and others predict future stocking based on variables that can be observed or specified before harvest.

In planning harvests and reforestation, management should give special attention to differences among geographic areas, forest types, and stands. The Dead Indian area has more severe ecological conditions than Butte Falls; thus, reforestation requires commensurately greater caution and attention. Clearcutting should not be ruled out completely in the southern Cascades. Used judiciously in conjunction with the best available planting technology, clearcutting should be appropriate in much of the Butte Falls area and for reestablishment of ponderosa pine and other frost-hardy species in the Dead Indian area. Prudent use of clearcutting requires better identification of locations or situations where the chances for frost damage during the growing season are low.

Seedling establishment is progressing satisfactorily in most partial cuts even before a technical regeneration cut has been made. There are problems to solve however, such as control of density, species, and genetic composition; prevention of disease infection from residual overstory; and acceleration of seedling growth. Planting under shelterwood may prove necessary to achieve prompt establishment, and control of species and genetic quality. Release of advance growth and establishment of new regeneration can be enhanced by preparing and following specific stand prescriptions. Where, how much, and how long to retain overstory are the foremost questions requiring research.

Abstract

Stein, William I.
1981. Regeneration outlook on BLM lands in the southern Oregon Cascades. USDA For. Serv. Res. Pap. PNW-284, 70 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A survey of cutover timberland in the Butte Falls and Dead Indian areas showed that most partial cuts were moderately or well-stocked with natural regeneration. Clearcuts in the Butte Falls area were also well-stocked, primarily with planted ponderosa pine; but many in the Dead Indian area were not. Advance regeneration was an important stocking component in partial cuts. Stocking varied by forest type, species, and drainage and correlated with an array of environmental variables. Regression equations describe present stocking patterns, and others predict future stocking based on variables that can be observed or specified before harvest.

Keywords: Regeneration (stand), regeneration (natural), regeneration (artificial), clearcutting systems, partial cutting, stand development, Oregon (Cascade Range).

Contents

Introduction

Forests in southwestern Oregon grow on a diversity of sites and contain a variable mix of species. After timber harvest, intense radiation, high temperatures, summer drought, drying winds, cold temperatures, and frosts are common obstacles to the reestablishment of conifers. Success of reforestation varies greatly, but the locations and situations where tree establishment is difficult or easy are not sufficiently identified.

In the early 1960's, the primary method of timber harvest used by the Medford District of the Bureau of Land Management (BLM), U.S. Department of the Interior, shifted from clearcutting to partial cutting. Difficulty experienced in artificially reforesting some clearcuts was a key reason for changing cutting practices. It was believed the environment provided by a partial overstory would permit ready establishment of natural regeneration. But this premise required confirmation.

After sufficient time had elapsed to permit establishment of regeneration, the Pacific Northwest Forest and Range Experiment Station and the Oregon State Office, Bureau of Land Management, jointly undertook an evaluation of reforestation on the Medford District. The study had two primary objectives: (1) evaluate in depth the results of reforestation efforts and (2) develop improved silvicultural guidelines for establishing conifer regeneration in southwestern Oregon. This paper summarizes information obtained by 1973-74 field surveys of cutovers located in Dead Indian and Butte Falls, the Cascade parts of the Medford District (fig. 1).

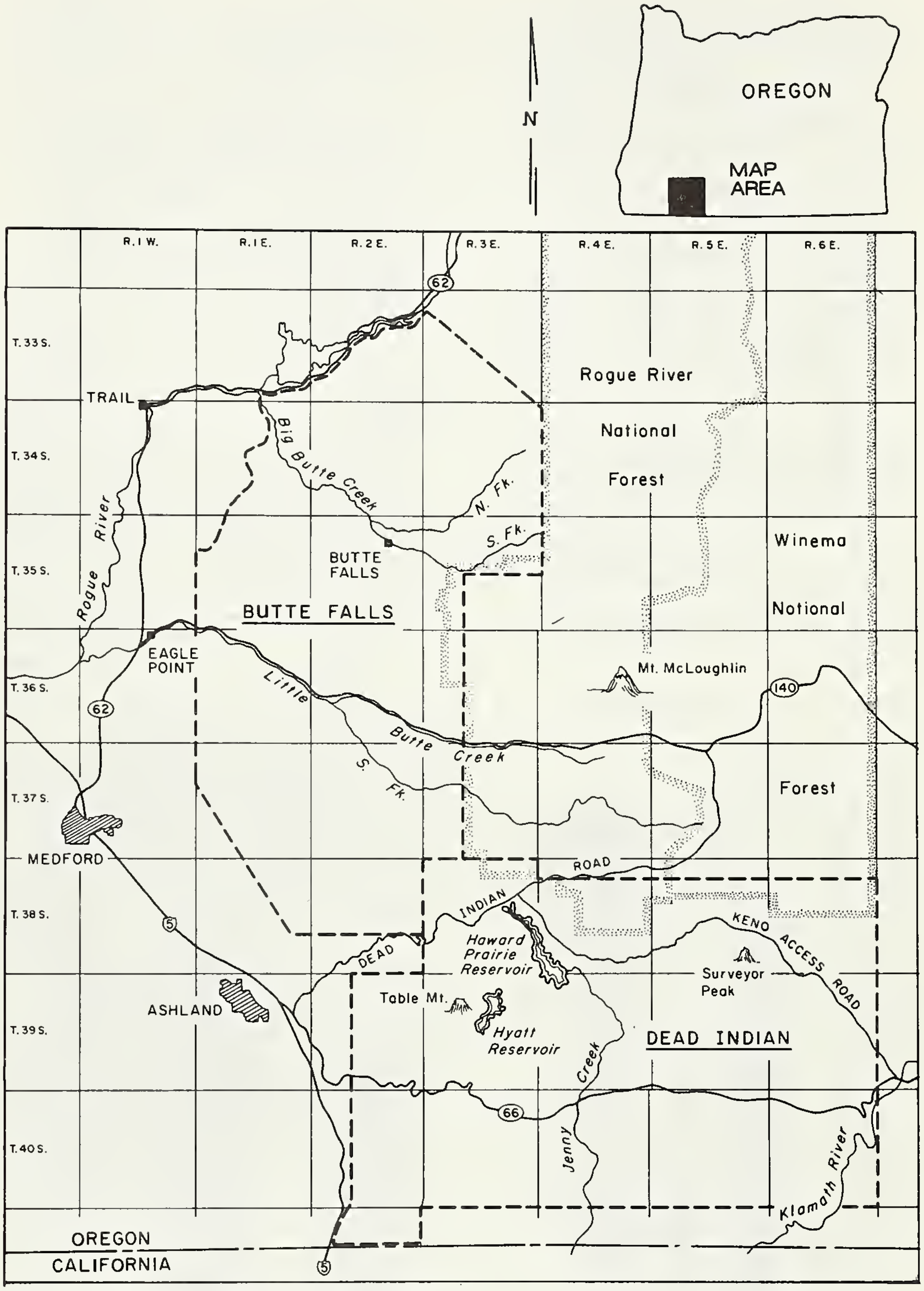

Figure 1.—The Butte Falls and Dead Indian areas are located to the northeast and southeast of Medford, Oregon.

Survey Methods

Survey methods were designed to answer these specific questions:

1. Of the area cut over in the 1956-70 period, what portion is now at least 30, 50, 70, and 90 percent restocked?

2. What is the composition of the stocking?
   a. Percent of area stocked by individual species?
   b. Percent of stocked area dominated by each species?
   c. Comparative stocking by seedlings of preharvest and postharvest origin?
   d. Portion of total stocking naturally established or artifically established?

3. Does stocking vary with changes in observed environmental variables?

4. What are the major regeneration problems?

5. Where are the chief problem areas?

Sample Selection

Sample plots were randomly located within BLM acreages clearcut or partially cut in the Dead Indian and Butte Falls areas during 1956-70. The cutovers were identified by section subdivisions, the forties (40 acres, a sixteenth of a section), in which they occurred. Primarily from photomap information, separate lists were compiled of all BLM forties in which 10 or more acres had been partially cut or clearcut. If a forty contained 10 or more clearcut acres and 10 or more partially cut acres, it was entered in both lists. All forties with sufficient cutting were listed, including those where cutting status or system were in doubt.

After forties in the lists had been numbered consecutively, tentative samples were selected by recording numbers in the order they were drawn from a random number table. Coordinates designating the exact location of the sample point (plot) in chains north and east of the southwest corner were then randomly assigned to each sample forty. When the designated sample point did not occur within cutover acreage, the sample was rejected. In successive random selections, the cutover acreage within a forty might be sampled more than once, each time at a point designated by a new set of randomly chosen coordinates.

These selection procedures resulted in a generous listing of forties and a consequent high rejection rate when sample points were not located in cutover areas or did not meet other criteria. Disposition of the first 214 candidate samples in partial cuts was as follows:

Plots		Percent
Sampled		30.4
Rejected:		69.6
Uncut	33.2	
Natural openings or scrub	9.4	
Cut over since 1970	12.6	
Cut over before 1956	6.5	
Clearcut	5.1	
Miscellaneous	2.8	
Total	69.6	100.0

Among the first 215 candidate samples in clearcuts, 25.6 percent were valid samples; 47.4 percent were rejected because the sample point was located in an uncut or partially cut stand; 22.8 percent were natural openings; and 4.2 percent were rejected for other reasons.

By the end of the 1973 field season, it became evident that the Butte Falls area was lightly represented among the first 55 plots sampled. It was evident too, that regeneration differed substantially between the Dead Indian and Butte Falls areas. A decision was then made to sample the Butte Falls area more intensively, and applicable samples for this purpose were drawn in sequence from the lists of candidate samples.

Plots and Subplots

Sample plots were found by hand compass and pacing. A land survey corner or section line marker at roadside was the usual starting point; but occasionally an identified road intersection, ownership boundary, or distinct geographic feature was used.

On each qualifying sample plot, circular 4-milacre subplots (1/250-acre; 0.00162-ha) were located at 1-chain intervals along four gridlines. If a subplot was clearly unsuited for establishment of regeneration, it was not sampled. The affected gridline was then extended a chain in the direction of travel to provide a replacement subplot.

A subplot was considered unsuited for regeneration establishment if any of these conditions prevailed on **more than half** its area:

1. Streambed up to normal high waterlines.
2. Permanent marsh, swamp, or meadow.
3. Road used since 1970.
4. Gravel pit used since 1970.
5. Solid rock, stump, or live tree stem.
6. Area of deep, active erosion.

Subplots were rejected on only 15 of the 92 plots sampled in the Dead Indian and Butte Falls areas. In total, 40 of 1,840 subplots were rejected, or 2.2 percent. Occurrence of the subplot on an actively used road was the cause for all but seven rejections.

Data Collected

Each subplot was thoroughly searched for seedlings. Stocking (occurrence) was determined for each species, but a count for total number was not made. Stocking was recorded by class of regeneration: (1) advance—healthy seedlings and saplings up to 8 inches (20 cm) in diameter, that originated before timber harvest; (2) subsequent—healthy seedlings originating after timber harvest and 2 or more years old; and (3) second-year—healthy seedlings still in their second season of growth. A species could have up to three entries per subplot, one for each class. Stocking was also recorded as being from natural seed fall, planting, or direct seeding. The species and class of regeneration most likely to become dominant on the subplot because of size, position, and competitive potential were also noted.

Environmental variables observed on each subplot were aspect, slope, canopy, total ground cover, dominant ground cover, seedbed, and seed source. If one variable—grass, gopher activity, low canopy, cattle damage, etc.— was considered a

primary help or hindrance to establishment of regeneration after timber harvest, it was also noted. Techniques used to collect and sum descriptive environmental data are detailed in the appendix, page 35.

Summaries and Analyses

Data were analyzed by several methods to answer the regeneration questions. Stocking data were summed and their means and standard errors calculated to ascertain current status of regeneration. Regression and correlation analyses tested relationships between stocking level and various environmental factors. The steps involved are outlined below; details are given with the results to which they pertain.

Stocking data for each sample plot were summarized by counting the subplots stocked by any species and by each species of advance, subsequent, and second-year regeneration. Summary tables showing total and other stocking classes were compiled individually for Dead Indian and Butte Falls partial cuts and clearcuts. Plots having more than 30-, 50-, 70-, or 90-percent stocking were counted, the totals were expressed as a percent of plots in the group, and confidence limits were determined for the resulting proportions from tables prepared by Mainland et al. (1956). Information on species composition, dominance, and abundance was similarly developed.

Preparation of environmental data used in correlation and multiple regression analyses required the calculation of plot averages for observed variables and those obtained from external sources. Tests for association between independent variables and the stocking found in Dead Indian and Butte Falls partial cuts and clearcuts were made by means of the BMD02R stepwise multiple regression computer program (UCLA version of April 13, 1965). Associations between some noncontinuous (discrete) independent variables—forest type, soil type, geographic location, etc.—and plot stocking were inferred from observed and demonstrated differences among groupings.

Stocking data for plots in partial cuts and clearcuts were summed to show average stocking, proportion of acreage stocked to a given level, and stocking by individual species. Information on species abundance and likely dominance was also developed.

Average Stocking

In broad terms, partial cuts in the Dead Indian area were moderately stocked with regeneration and those in the Butte Falls area were well stocked.[1] Established regeneration averaged 65 percent in the Dead Indian area[2] and 81 percent in the Butte Falls area (fig. 2, and table 12, appendix). Total stocking ranged widely among Dead Indian partial cuts, from a low of 5 percent to 100 percent, and more narrowly for those in Butte Falls, from 50 to 100 percent.

[1]Stocking classes, as defined by the Pacific Northwest Seeding and Planting Committee (Reynolds et al. 1953): well stocked, 70 - 100 percent; moderately stocked, 40 - 69; poorly stocked, 10 - 39; and nonstocked, 0 - 9.

[2]Total stocking also averaged 65 percent for eight Dead Indian partial cuts omitted from all analyses. These sample plots were omitted because elapsed time after logging was not accurately known during sampling; this resulted in uncertain allocation of seedlings to advance and subsequent regeneration classes.

Figure 2.—Regeneration in partial cuts, by class. Data are not additive since more than one class of regeneration was found on many subplots.

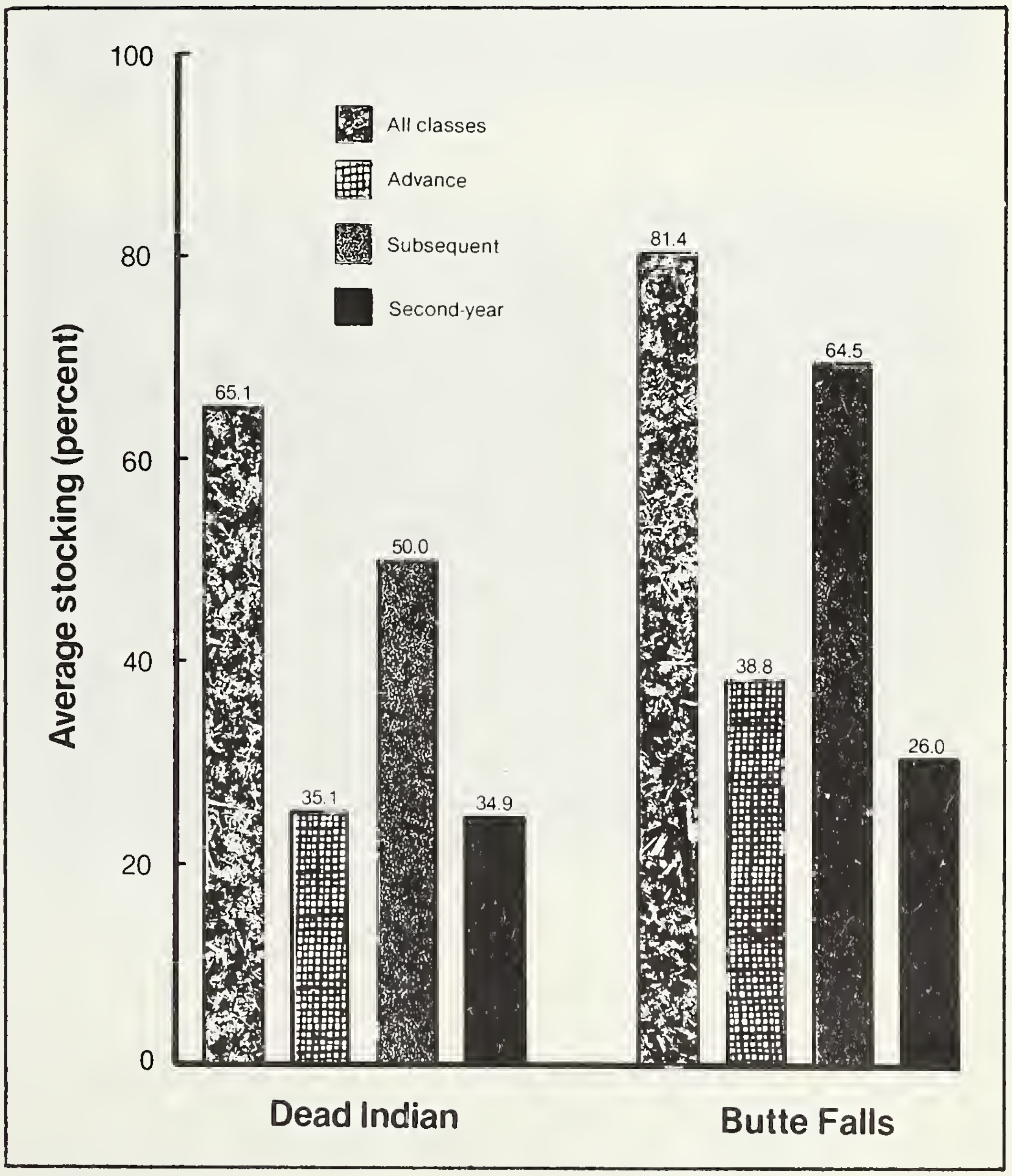

Figure 3.—Regeneration established before logging constituted about half the total stocking found in partial cuts.

Figure 4.—In general, partial cuts were moderately stocked with regeneration that established after logging.

After logging, the amount of advance regeneration in partial cuts was about the same in the two areas, averaging 35-percent stocking in Dead Indian and 39-percent in Butte Falls. The amount varied widely on individual plots—from 5 to 85 percent in Dead Indian and from 5 to 75 percent in Butte Falls. Advance regeneration constituted just over half the total stocking in the Dead Indian area and just under half in the Butte Falls area. From the standpoint of amount present and size of trees, advance regeneration constituted a highly important component of total stocking in partial cuts (fig. 3).

In both the Dead Indian and Butte Falls areas, partial cuts were moderately stocked with regeneration that established after logging (fig. 4). On the average, 50 percent of the subplots examined in Dead Indian partial cuts were stocked with subsequent regeneration; 65 percent in Butte Falls (fig. 2., table 12, appendix). Again, the amount of stocking varied widely among plots, from 0 to 95 percent in Dead Indian, 5 to 100 percent in Butte Falls. Postlogging regeneration constituted a little over three-fourths of the total stocking found in Dead Indian and Butte Falls partial cuts, if such regeneration is considered the main component rather than a subsidiary component of total stocking.

Substantial numbers of second-year seedlings were found in both Dead Indian and Butte Falls partial cuts. These were not tallied as part of total stocking since their survival through two full growing seasons had not yet been demonstrated. From their appearance, the long-term survival of many seemed assured. In only a few instances, however, would the potential of these seedlings materially boost total stocking for the area. For example, potential for increased stocking was found on 26 of the 44 plots examined in Dead Indian, but only on 5 was the potential gain more than 15 percent; on 2 areas, the potential was sufficient to raise an essentially nonstocked area to moderate stocking and on 2 others from poorly stocked to well stocked. In Butte Falls, only four partial cuts had potential for gain in stocking

from second-year seedlings, none greater than 5 percent. The primary effect of the continued survival of second-year seedlings will be to increase numbers of seedlings on subplots that are already stocked.

In general, clearcuts in the Dead Indian area were poorly stocked; those in the Butte Falls area were well stocked (fig. 5). Total stocking averaged 33 percent on Dead Indian clearcuts; more than twice as much —74 percent—on Butte Falls clearcuts (fig. 6, and table 12, appendix). One clearcut plot in Dead Indian had no seedlings at all, and the highest stocking was 75 percent. In contrast, the lowest stocking on a Butte Falls clearcut was 55 percent, the highest 90 percent.

Clearcuts were not entirely devoid of advance regeneration. Six of 16 clearcuts sampled in the Dead Indian area and 7 of 11 clearcuts in the Butte Falls area had minor amounts of regeneration that survived logging and any slash burning. Average stocking with advance regeneration was low, 4 percent for Dead Indian, 9 for Butte Falls, and constituted about one-eighth of total stocking.

Relative amounts of regeneration that established after logging paralleled trends in total stocking; on the average, Dead Indian clearcuts were poorly stocked and Butte Falls clearcuts well stocked with subsequent regeneration. In neither area was there significant potential for increased stocking from second-year seedlings. In fact, on only one subplot of one clearcut were second-year seedlings the only regeneration present. Clearly, accretion of seedlings is not occurring on clearcuts in quantities similar to those in partial cuts.

A

B

Figure 5.—Clearcuts were generally poorly stocked in the Dead Indian area (**A**), well stocked in the Butte Falls area (**B**).

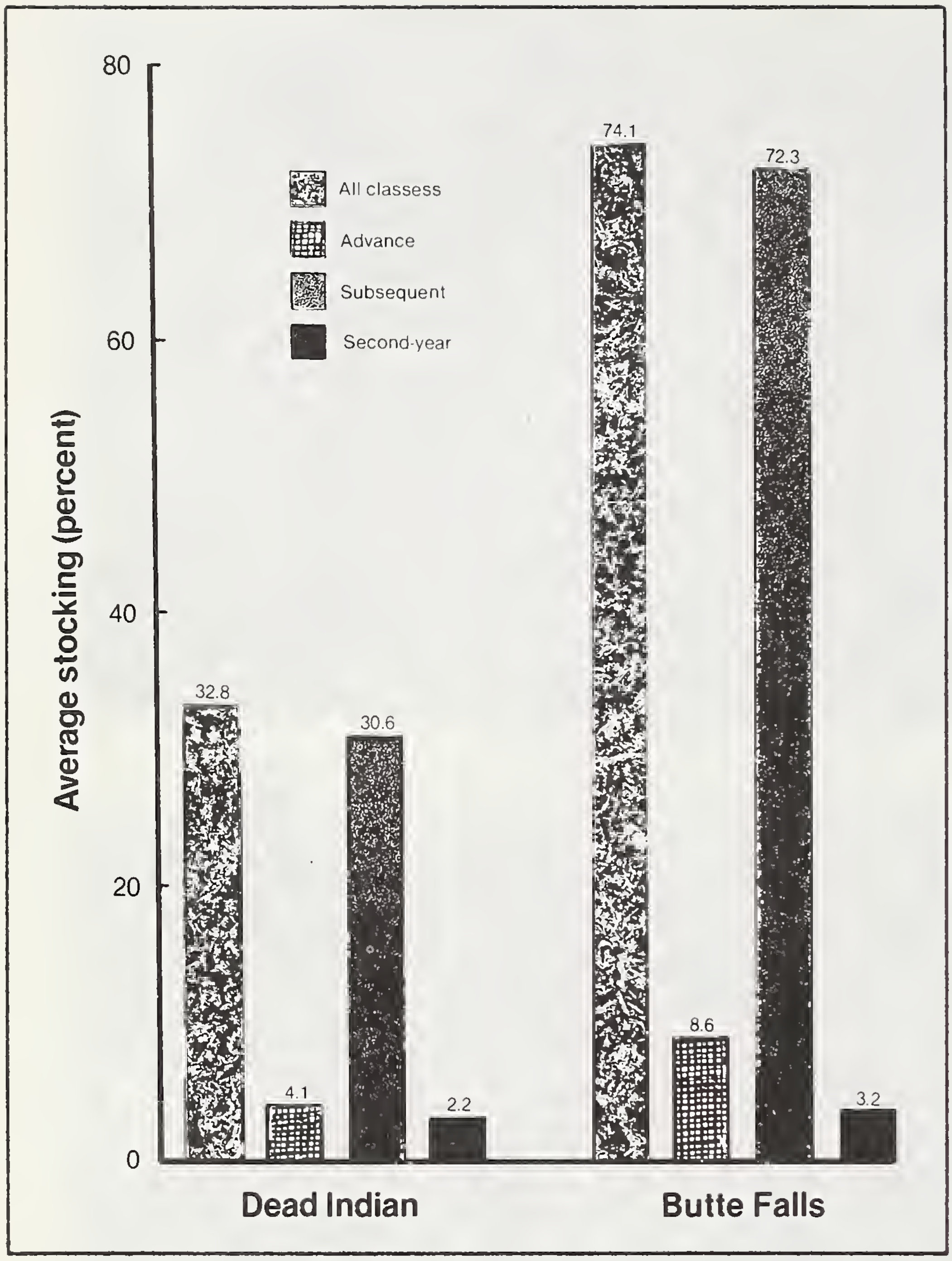

Figure 6.—Regeneration in clearcuts, by class.

Stocking Levels

The proportion of plots stocked to the 30-, 50-, 70-, and 90-percent levels was determined to augment information on average stocking. To facilitate presentation and illustrate significance of data on stocking levels, let us assume that 50 percent is the dividing line between acceptable and unacceptable stocking. Areas less than 50 percent stocked might then be viewed as requiring additional regeneration effort.

Three-fourths of the acreage partially cut in the Dead Indian area between 1956 and 1970 now meets the 50-percent or better stocking level (fig. 7, and table 13, appendix). All the partially cut or clearcut acreage in the Butte Falls area meets or exceeds the 50-percent level, but only one-fourth of the clearcut acreage in Dead Indian does (figs. 7 and 8, and table 13, appendix). In partial cuts, stocking from natural regeneration was so uniform and high that a significant amount of the acreage—43 percent in Butte Falls, 18 in Dead Indian—meets or exceeds the 90-percent stocking level.

About one-fourth of the partially cut acreage in Dead Indian and four-tenths in Butte Falls was stocked with advance regeneration at the 50-percent level or higher (table 14, appendix). In both Dead Indian and Butte Falls, about one partial cut in eight had as much as 70-percent stocking of advance regeneration after the first or second cut. Little of the clearcut acreage had 30-percent stocking of advance regeneration.

All clearcuts in the Butte Falls area were 50 percent stocked or better with subsequent regeneration, but only one-fourth of those in the Dead Indian area were (table 15, appendix). Most partial cuts in Butte Falls had reached the 50-percent level, but in Dead Indian, just over half had attained this level.

Stocking levels for Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) and true firs, the most common species to establish naturally after logging, also were different between Butte Falls and Dead Indian areas and between clearcuts and partial cuts (tables 16 and 17, appendix). For example, about three-tenths of the partial cutting in Butte Falls had 50-percent or more stocking of Douglas-firs but less than a tenth of the partial cuts in Dead Indian did. A third of the clearcuts in Butte Falls had reached 30-percent or more stocking of Douglas-fir, but none in Dead Indian had. Over half the partial cuts in both the Dead Indian and Butte Falls areas had at least 30-percent stocking of true firs, but few clearcuts in either area had reached this level.

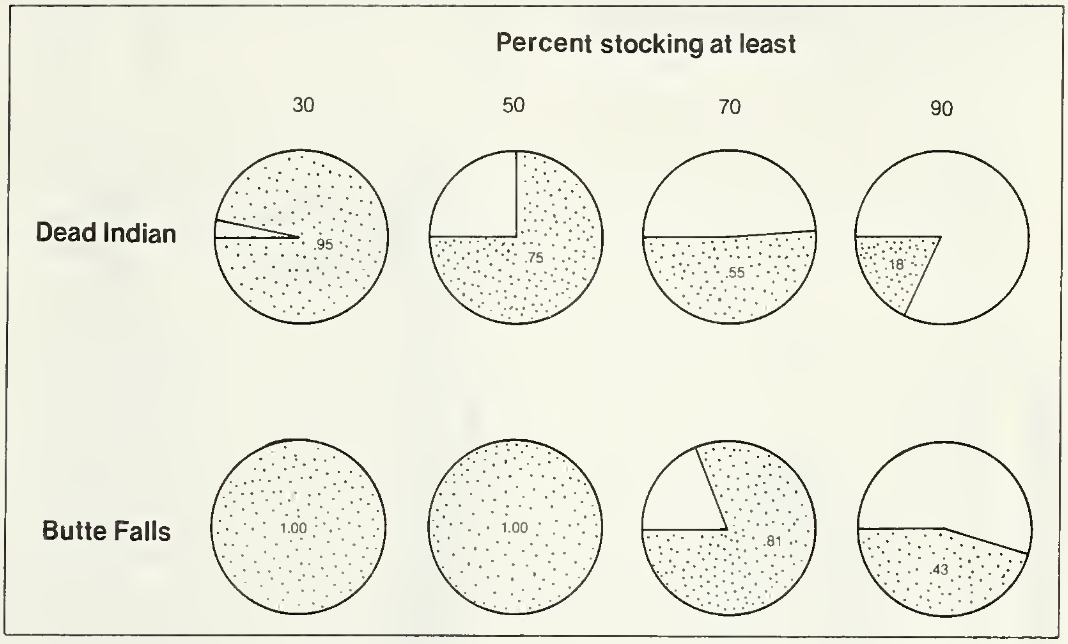

Figure 7.—Proportion of acreage partially cut from 1956 to 1970 that was 30-, 50-, 70-, or 90-percent stocked with regeneration.

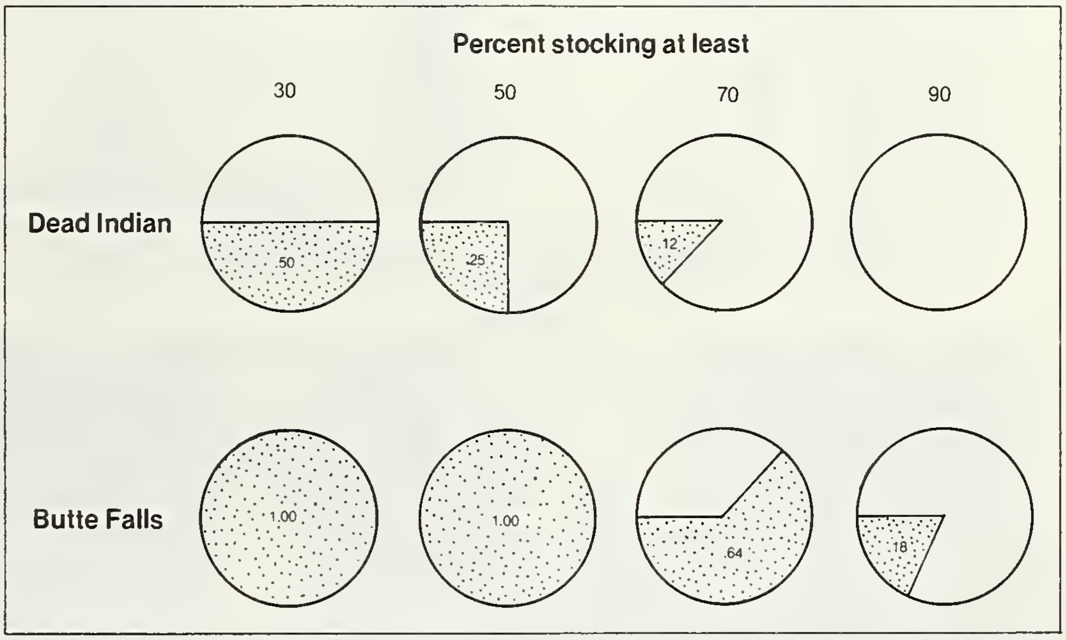

Figure 8.—Proportion of acreage clearcut from 1956 to 1970 that was 30-, 50-, 70-, or 90-percent stocked with regeneration.

Stand Composition

Many native conifers and a few hardwoods were found on the plots sampled. Douglas-fir and true firs were commonly present. True fir regeneration was not identified by species; in different parts of the areas, it included white fir (*Abies concolor* (Gord. and Glend.) Lindl. ex Hildebr.), grand fir (*A. grandis* (Dougl. ex D. Don) Lindl.), and Shasta red fir (*A. magnifica* var. *shastensis* Lemm.). Conifers found in lesser quantities and not universally distributed included ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), sugar pine (*P. lambertiana* Dougl.), western white pine (*P. monticola* Dougl. ex D. Don), lodgepole pine (*P. contorta* Dougl. ex Loud.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), incense-cedar (*Libocedrus decurrens* Torr.), and Pacific yew (*Taxus brevifolia* Nutt.). Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.), not native in most of the Butte Falls and Dead Indian areas, was planted in mixture with ponderosa pine on a few clearcuts. Regeneration of large hardwoods found in minor quantities included giant chinkapin (*Castanopsis chrysophylla* (Dougl.) A. DC.), western serviceberry (*Amelanchier alnifolia* (Nutt.) Nutt.) quaking aspen (*Populus tremuloides* Michx.), Pacific madrone (*Arbutus menziesii* Pursh), Oregon white oak (*Quercus garryana* Dougl. ex Hook.), bigleaf maple (*Acer macrophyllum* Pursh), red alder (*Alnus rubra* Bong.), and bitter cherry (*Prunus emarginata* Dougl. ex Eaton).

True firs predominated among regeneration in partial cuts (fig. 9, and table 18, appendix). They were present on five of every six stocked subplots (54.2 ÷ 65.1 = .833) in the Dead Indian area and on 7 of 10 in the Butte Falls area. Douglas-fir regeneration was next most abundant—found on about 3 of every 10 stocked subplots in Dead Indian and on 6 of 10 in Butte Falls. Incense-cedar was third in abundance, being present on one of five stocked subplots in Dead Indian and on slightly more than half in Butte Falls. Other species were found less frequently than on 1 stocked subplot in 10.

Ponderosa pine was the predominant species in clearcuts in both the Dead Indian and Butte Falls areas (fig. 10, and table 18, appendix). It was present on slightly more than half the

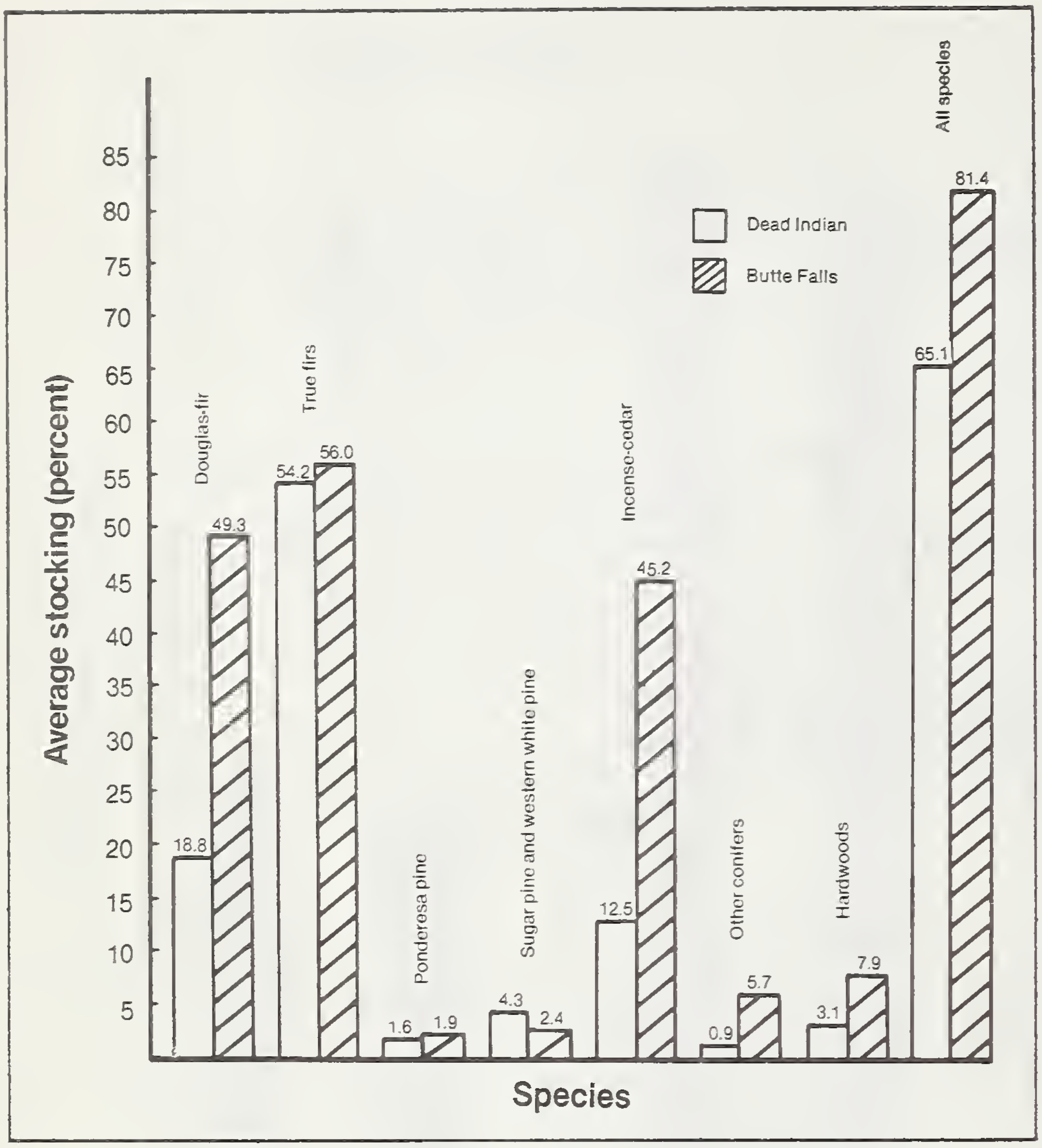

Figure 9.—Average stocking by species in Dead Indian and Butte Falls partial cuts.

stocked subplots in Dead Indian and on four of five in Butte Falls. Douglas-fir was second in frequency of occurrence in Butte Falls clearcuts but was exceeded 3 to 1 by true firs in Dead Indian clearcuts.

Advance true firs were present on five of every six subplots stocked with advance regeneration in Dead Indian partial cuts and on two of every three in Butte Falls (table 19, appendix). Douglas-fir advance regeneration was found on only one of every nine stocked subplots in Dead Indian partial cuts and on less than one of two in Butte Falls. Advance regeneration of other conifers and hardwoods was present only in minor quantities in the Dead Indian area, but incense-cedar was present on about one of every four subplots stocked with advance growth in the Butte Falls area.

True firs also predominated among advance regeneration in clearcuts in both locations (table 19, appendix). In Butte Falls, however, occurrence of Douglas-fir advance regeneration approached that of true firs. No ponderosa pines were found among the sparse advance regeneration in clearcuts, but there were a few five-needle pines and incense-cedars.

Subsequent Douglas-firs and true firs occurred with equal frequency in Butte Falls partial cuts, on 6 of every 10 stocked subplots (table 19, appendix). In Dead Indian partial cuts, true firs occurred on more than twice as many stocked subplots as did Douglas-fir, 3 of 4 and 3 of 10, respectively. Six-tenths of the subplots stocked with subsequent regeneration in Butte Falls partial cuts contained incense-cedar; in Dead Indian partial cuts, about one-fourth of the stocked subplots included incense-cedar. As a proportion of stocking by all species, Douglas-fir, five-needle pines, and incense-cedar were more abundant among subsequent seedlings in partial cuts than they were among advance regeneration. True firs and hardwoods occupied a somewhat smaller proportion of subplots stocked with subsequent regeneration than they did among subplots stocked with advance regeneration.

Ponderosa pine was the most common species established after logging in both Dead Indian and Butte Falls clearcuts (table 19, appendix). It was present on 6 of 10 stocked subplots in Dead Indian clearcuts and 8 of 10 in Butte Falls. Predominance of ponderosa pine in clearcuts reflects success achieved in planting this species (fig. 11). True firs were second and Douglas-fir third most common on stocked subplots in Dead Indian and in reverse order in Butte Falls. Incense-cedar occurred on about 1 of 11 stocked subplots in Butte Falls. Seedlings of all species found except ponderosa pine, Jeffrey pine, and Douglas-fir were judged to have established naturally from seed.

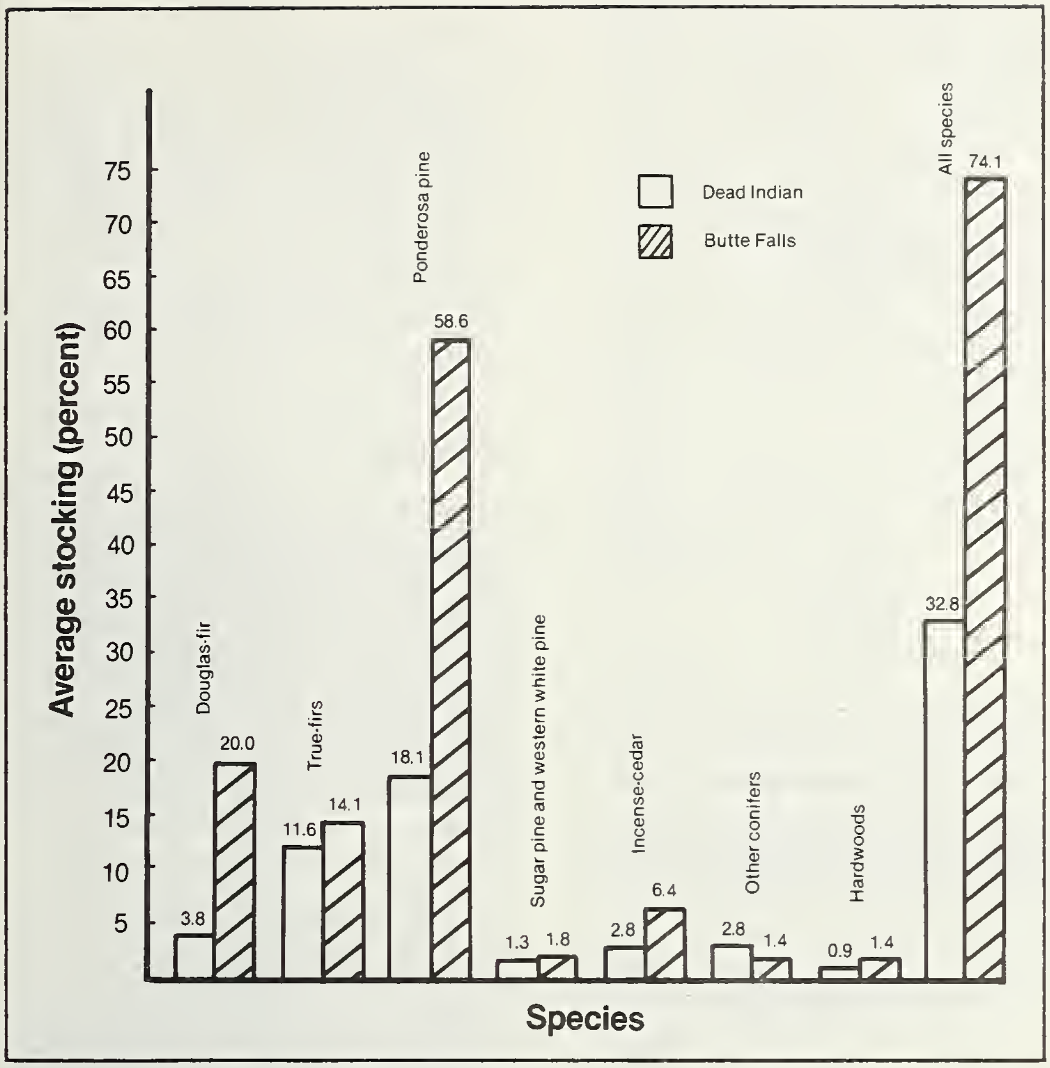

Figure 10.—Average stocking by species in Dead Indian and Butte Falls clearcuts.

Figure 11.—Ponderosa pine was the predominant species in both Dead Indian (**A**) and Butte Falls (**B**) clearcuts.

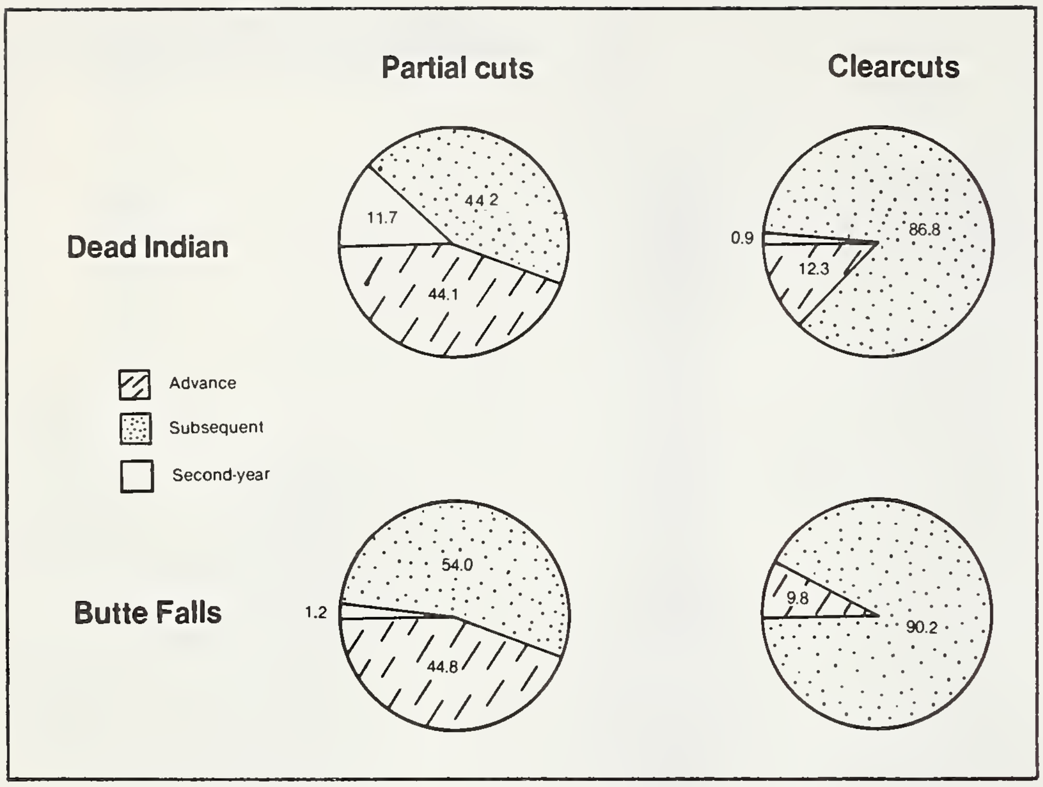

Figure 12.—Advance regeneration dominated nearly half the stocked subplots in partial cuts.

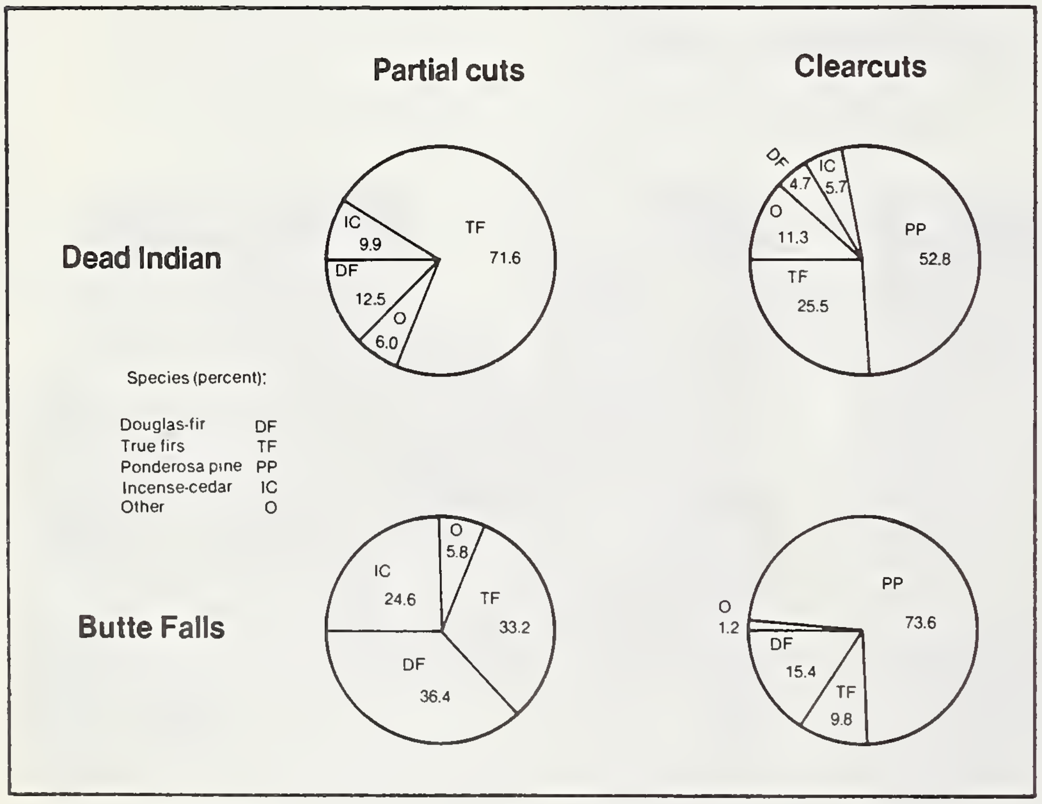

Figure 13.—Species dominant on stocked subplots differed between partial cuts and clearcuts.

Many second-year seedlings were found in partial cuts, very few in clearcuts (table 20, appendix). On a stocking basis, one-eighth as many young seedlings were found in Butte Falls and one-sixteenth as many in Dead Indian clearcuts as in respective partial cuts. Young true firs stocked more subplots than any other species, except in Butte Falls partial cuts where incense-cedar was most common.

Dominance

Future composition of the developing stand may be more closely related to class of regeneration and species that now dominate stocked subplots than to the number of subplots on which each occurs. For this reason, the class of regeneration and the species dominant on each subplot were tabulated. Second-year seedlings were included, for these represent potential when nothing older already dominates the subplot.

Advance regeneration dominated nearly half the stocked subplots in both Dead Indian and Butte Falls partial cuts; only about 10 percent in clearcuts (fig. 12). Only in Dead Indian partial cuts did second-year seedlings constitute an important component among dominants—12 percent.

True firs, Douglas-fir, and incense-cedar were the dominant species of regeneration in Dead Indian and Butte Falls partial cuts (fig. 13). As individual species, pines, hardwoods, and miscellaneous conifers were dominant on 3 percent or less of the total stocked subplots. In clearcuts, one of two stocked subplots in Dead Indian, and three of four in Butte Falls were dominated by ponderosa pine (fig. 13). True firs and incense-cedar ranked second and third in Dead Indian clearcuts; Douglas-fir and true firs ranked second and third in Butte Falls clearcuts.

Species Abundance

In this survey, the presence or absence of seedlings was determined, not the total number. Since each subplot was searched for individual species, however, some information on stand mixtures can be deduced from the stocking data.

In general, mixed regeneration was more common in the Butte Falls area than in the Dead Indian area. Only a third of the stocked subplots in Butte Falls partial cuts contained only one species, but nearly two-thirds of those in Dead Indian did (table 1); differences were not as great in clearcuts—72 percent for Butte Falls and 79 percent for Dead Indian. Both partial cuts and clearcuts in Butte Falls had appreciable numbers of subplots stocked with three or more species. Widespread occurrence of species mixtures is prerequisite to flexible management of the developing stand.

Presence of more than one species also provides direct evidence that many subplots were stocked with more than one tree. Data in table 1 indicate that in the cutovers sampled, 21 to 68 percent of the subplots were stocked with more than one species. Certainly, the percent of subplots that had more than one tree of the same species was even higher.

Regeneration survey objectives included a search for interdependence of environmental factors and seedling stocking and the identification of problem areas. Two kinds of analysis were used: (1) comparison of means after stocking data were sorted on the basis of discontinuous environmental variables—forest type, soil type, etc.; and (2) correlation and regression analyses testing for associations between stocking and independent environmental variables of a continuous nature—elevation, slope, canopy, etc. Environmental information obtained for the Dead Indian and Butte Falls areas is presented before results of the two types of analysis are given.

Geographic Characteristics

Environments in the Dead Indian and Butte Falls areas differ substantially. The differences are somewhat evident from the nature of the forests and other vegetation. The degree of difference, however, is much greater than is evident during casual work or travel in the areas. A systematic comparison of environmental factors determined for sample plots forcefully demonstrates some key differences.

All partial cuts and clearcuts sampled in the Dead Indian and Butte Falls areas were located on gentle terrain. Slopes on plots ranged from flat ground to a maximum of 38 percent (table 2). Slopes averaged 10 percent in Dead Indian and 15 percent in Butte Falls. Although there are prominent hilltops and mountain peaks in both, the Dead Indian and Butte Falls areas have many plateaulike features.

Elevation of these areas, however, is substantially different. Elevation for plots sampled in Butte Falls averaged 3,524 feet (1 074 m), for Dead Indian 4,948 feet (1 508 m), a difference of more than 1,400 feet (427 m). Only elevations of the three highest plots sampled in Butte Falls overlap the lowest elevation sampled in the Dead Indian area. In both areas, clearcuts averaged somewhat lower in elevation than partial cuts.

It is evident from elevation differences alone that growing seasons in the Butte Falls and Dead Indian areas differ substantially in temperature and length. Application of the adiabatic gradient (5.6°F per 1,000 ft or 1°C per 100 m) provides some insight on relative temperatures. When summer temperatures register 100°F (38°C) in the shade at 1,300-foot (396-m) elevation near Medford, temperatures are about 88°F (31°C) in the Butte Falls area and about 80°F (27°C) in the Dead Indian area. Relative to valley temperatures near Medford, neither area is exceptionally hot; and the Dead Indian area is much cooler than the Butte Falls area.

Topographic position of these areas is also quite different. The Butte Falls area, hilltops included, occupies a midslope position relative to the Rogue River Valley to the west and the higher Cascades to the east. In contrast, much of the Dead Indian area occupies upper slope positions. Drainages from the westernmost part of Dead Indian flow westward, then north to the Rogue River via Bear Creek; others flow northwestward to the Rogue via Dead Indian and Little Butte Creeks; but most of the area drains south and southeastward to the Klamath River via Jenny Creek

Table 1—Number of species per stocked subplot in partial cuts and clearcuts

Species per subplot	Partial cuts		Clearcuts	
	Dead Indian	Butte Falls	Dead Indian	Butte Falls
	Percent of stocked subplots			
1	61.2	31.5	79.2	71.8
2	31.0	34.1	17.0	16.6
3	7.4	27.4	1.9	10.4
4	.4	5.8	1.9	.6
5	0.	.6	0.	.6
6	0.	.6	0.	0.
Total	100.0	100.0	100.0	100.0

Table 2—Physical characteristics of sampled areas

Characteristic	Dead Indian		Butte Falls	
	Partial cuts	Clearcuts	Partial cuts	Clearcuts
	Number of areas			
Drainage:				
Jenny Creek	31	7	0	0
Big Butte Creek	0	0	11	7
Klamath River	8	1	0	0
Little Butte Creek	3	7	3	0
Rogue River	0	0	7	4
Bear Creek	2	1	0	0
Total	44	16	21	11
Predominant aspect:				
SE to W	21	9	13	5
NW to E	23	7	8	6
Soil type:[1]				
740	0	0	3	0
750	0	0	11	10
809	30	15	0	0
810	7	1	7	1
840	2	0	0	0
850	1	0	0	0
882	4	0	0	0
Radiation index:				
Average	.4721	.4532	.4626	.4608
Range	.4223-.5315	.3972-.4806	.3457-.5177	.4202-.5006
Elevation:[2]	Feet			
Average	4,965	4,901	3,612	3,355
Range	4,400-5,720	4,560-5,700	2,600-4,840	2,920-4,260
Precipitation:[3]	Inches			
Average annual	29.9	22.6	40.5	38.5
Range	18-40	18-30	30-50	25-50
Slope:	Percent			
Average	9.5	11.0	13.6	16.5
Range	0-35	0-32	0-33	0-38
Seedbed disturbance				
Average	63.0	94.1	50.7	87.7
Range	30-100	85-100	10-95	60-100

[1]Descriptions for numbered soil types are in a compendium on file at Medford District, Bureau of Land Management.

[2]To convert feet to meters, multiply by 0.305.

[3]To convert inches to centimeters, multiply by 2.54.

and adjacent drainages (fig. 1, table 2). Many more sites in the Dead Indian area appear frontally exposed to strong winds and to climatic extremes than in the Butte Falls area.

Limited records indicate that the Butte Falls area receives substantially more precipitation than does the Dead Indian area. As extrapolated from a small-scale isohyet map which probably is only a first approximation of rainfall distribution in the areas, precipitation averages 30 inches (76 cm) per year for the partial cuts sampled in Dead Indian, about 40 inches (103 cm) for those in Butte Falls. Precipitation on the clearcuts sampled is somewhat lower, averaging 23 inches (57 cm) in Dead Indian, 38 inches (98 cm) in Butte Falls. Judged by data for plot locations, precipitation ranges from 18 to 40 inches (46 to 102 cm) in Dead Indian, 25 to 50 inches (64 to 127 cm) in Butte Falls.

That midslopes around Butte Falls receive more rainfall than higher slopes only 25 miles (40 km) southward may appear surprising. Undoubtedly, the smoothing and extrapolation needed to prepare the isohyet map could produce some inconsistencies. Broad vegetation patterns, however, support the precipitation levels indicated by the isohyet map. Evergreen brush and forest communities occur at substantially lower elevations on the western fringes of the Butte Falls area than on the Dead Indian area. Perhaps the eastern Siskiyou Mountains, which rise to 7,533-foot elevation (2 296 m) only 15 miles (24 km) to the southwest across the intervening valley, produce a rain shadow effect on the westernmost Dead Indian slopes which rise to a maximum of 6,113 feet (1 863 m).

Southerly (SE to W) and northerly (NW to E) aspects were about equally represented among sample plots in the Dead Indian and Butte Falls areas (table 2). Average radiation indexes were also similar, indicating that slope and aspect combinations were not markedly dissimilar in the two areas. Dead Indian clearcuts averaged less radiation (lower radiation index values) than the rest.

Sample plots in both the Dead Indian and Butte Falls areas were located on well-drained loam soils, originating from basic volcanic rocks of the Cascade Range. Except for their gravel or cobble content and depth, descriptions of these soils are not markedly different:

Series	Surface: Texture	Surface: Color	Depth: Surface	Depth: Total
			(Inches)[3]	
740	Cobbly loam	Dark brown	24	50
750	Clay loam	Dark reddish brown	14	60
809	Very cobbly loam	Very dark grayish brown	12	36
810	Cobbly loam	Very dark grayish brown	22	45
840	Gravelly loam	Very dark grayish brown	12	55
850	Clay loam	Dark brown	12	36
882	Very cobbly loam	Dark brown	19	45

[3]See footnote 3, table 2.

Table 3—Vegetative characteristics of sampled areas

Characteristic	Dead Indian		Butte Falls	
	Partial cuts	Clearcuts	Partial cuts	Clearcuts
	Number of areas			
Forest type:				
White fir	22	9	7	5
Douglas-fir	8	7	13	6
Ponderosa pine	6	0	0	0
Pine mixture	3	0	1	0
Sugar pine	3	0	0	0
Shasta red fir	2	0	0	0
Total	44	16	21	11
Dominant cover:				
Woody perennial	22	3	14	7
Herbaceous	18	3	6	4
Grass	3	10	1	0
Bare	1	0	0	0
Main seed source:				
True fir	31	3	4	0
Douglas-fir	7	13	16	9
Incense-cedar	5	0	1	0
Ponderosa pine	0	0	0	1
Sugar pine	1	0	0	1
	Years			
Time since harvest:				
Average	7.5	12.8	6.6	13.0
Range	2-16	8-16	2-14	9-15
	Percent			
Canopy:				
Average	43.7	9.9	45.6	31.6
Range	21-71	1-25	22-74	15-52
Ground cover:				
Average	49.0	61.0	48.2	61.0
Range	18-83	35-81	17-77	54-69
Seed Source Within 50 feet:				
Average	97.4	33.8	96.2	20.5
Range	55-100	0-70	75-100	0-55

It is likely, but not absolutely certain, that the 2-acre (0.8-ha) plot sampled at each location was on soil typical of the series.

Two-thirds of the plots sampled in the Butte Falls area were located on a dark reddish brown clay loam, the deepest soil represented. Three-fourths of the plots in the Dead Indian area were located on a very dark grayish brown, very cobbly loam of medium depth. Many of the remaining plots in both areas were located on very dark grayish brown cobbly loam (series 810) whose depth is intermediate to series 750 and 809. In broad terms, plots in Butte Falls were located on soils that are finer, deeper, and have greater water-holding capacity than the soils in Dead Indian.

During logging, a high percentage of the seedbed surface on both Butte Falls and Dead Indian clearcuts was disturbed—88 and 94 percent, respectively, as judged by evidence still visible several years later. Much less seedbed was disturbed in the partial cuts, averaging 51 percent for Butte Falls and 63 percent for Dead Indian. Lowest disturbance in partial cuts was 10 percent; in clearcuts, 60.

Vegetation Characteristics

Plots sampled in the Dead Indian or Butte Falls areas occurred in the Douglas-fir, white fir, ponderosa pine, pine mixture, sugar pine, and Shasta red fir forest types. At each plot location, the type was determined from Forest Survey maps prepared in the 1940's. Thus, the classification antedates any compositional changes caused by logging. For study purposes, the mapped subdivisions of each type were not kept separate.

All clearcuts sampled were located in either the Douglas-fir or white fir type (table 3); the two types were equally represented. For partial cuts, white fir type was predominant among Dead Indian samples, Douglas-fir among Butte Falls samples. Pine types were strongly represented among samples from Dead Indian partial cuts, more so than the Douglas-fir type.

On the average, the clearcuts were older than the partial cuts, 13 years compared with 7. By design, all sample areas had been logged at least 2 years earlier and none more than 18.

Dead Indian and Butte Falls partial cuts averaged about the same overstory canopy, 45 percent. The means for 20 ocular estimates of canopy per individual plot ranged from 21 to 74 percent (fig. 14). Scattered residual trees were sometimes present on clearcuts, but young trees and shrubs over waist high constituted most of the canopy. Clearcuts in Dead Indian were relatively open, averaging about 10-percent canopy; those in Butte Falls averaged over 30-percent canopy.

Ground cover averaged 61 percent in clearcuts, 49 percent in partial cuts. Variability in amount of ground cover was greatest in partial cuts, from 17 to 83 percent. Woody perennials and herbaceous types of vegetation were dominant on nearly equal numbers of Dead Indian partial cuts; the majority of clearcuts were dominated by grass. In Butte Falls, woody perennials were the dominant ground cover on a majority of the partial cuts and clearcuts (fig. 15).

Nearly all subplots examined in partial cuts were located within 50 feet (17 m) of a seed tree; but on clearcuts, one-third or less of the subplots were within 50 feet of a seed tree. True firs were the predominant species of seed tree in a majority of Dead Indian partial cuts. Douglas-fir was the predominant seed tree in Butte Falls partial cuts and also adjacent to Dead Indian and Butte Falls clearcuts. Incense-cedar was the predominant seed tree in six instances, ponderosa or sugar pine in only three. On more than 80 percent of the plots examined, at least two species were represented among the closest seed trees.

Figure 14.—Overstory canopy in partial cuts varied greatly in quantity and distribution.

Figure 15.—Woody perennials, such as ceanothus, chinkapin, and manzanita, were the dominant ground cover in Butte Falls clearcuts and partial cuts.

Stocking by Forest Type

Sample plots were sorted by the forest types in which they occurred. Averages for the four classes of regeneration—all, advance, subsequent, and second-year—were then determined for each type, cutting method, and locality. Differences between means representing three or more plots per grouping were tested for significance by analysis of variance and Duncan Multiple Range Tests (Duncan 1955). Although forest types are not represented by an equal number of plots and some groupings have insufficient data, the demonstrated statistical differences and the consistency of various differences provide useful insights.

In partial cuts, both total stocking and subsequent stocking averaged lower in the white fir than in the other forest types sampled (table 4). The difference was substantial—14 percent lower than the next higher average for total stocking and 17 percent lower for subsequent stocking. The same relationship holds for the Dead Indian and Butte Falls areas individually, but differences are not as great.

Advance regeneration tends to be less abundant in the Douglas-fir type than in the white fir, ponderosa pine, and Shasta red fir types. Furthermore, potential for gain in stocking from second-year seedlings was generally less in the Douglas-fir than in the other three types. Scarcity of young seedlings might only reflect timing relative to occurrence of the last seed crop. But good stocking in the type, despite sparse numbers of advance and second-year seedlings, might indicate that seedlings must establish soon after harvest rather than through steady accretion.

Table 4—Average and range of stocking by forest type in Dead Indian and Butte Falls partial cuts

Area and forest type	Sample plots	Regeneration class[1]							
		All		Advance		Subsequent		Second-year	
		Average	Range	Average	Range	Average	Range	Average	Range
	Number	Percent stocking							
Dead Indian:									
White fir	22	58.2a	10- 90	35.5b	5-70	39.8ab	0- 90	37.0	5-75
Douglas-fir	8	63.8	35- 90	17.5bc	5-45	59.4a	25- 90	32.5	15-75
Pine	12	74.6a	5-100	42.5c	5-75	58.8b	0- 95	29.6	5-80
Shasta red fir	2	90.0	80-100	57.5	30-85	72.5	70- 75	52.5	35-70
Total or average	44	65.1	5-100	35.1	5-85	50.0	0- 95	34.9	5-80
Butte Falls:									
White fir	7	74.3	50-100	42.9	20-75	60.0	35- 80	32.1	0-90
Douglas-fir	13	84.6	55-100	37.7	5-70	65.0	5-100	19.6	5-65
Pine	1	90.0	--	25.0	--	90.0	--	65.0	--
Total or average	21	81.4	50-100	38.8	5-75	64.5	5-100	26.0	0-90
Dead Indian and Butte Falls:									
White fir	29	62.1ab	10-100	37.2	5-75	44.7bb_1	0- 90	35.9	0-90
Douglas-fir	21	76.7b	35-100	30.0	5-70	62.9b	5-100	24.5	5-75
Pine	13	75.8a	5-100	41.2	5-85	61.2b_1	0- 95	32.3	5-80
Shasta red fir	2	90.0	80-100	57.5	30-85	72.5	70- 75	52.5	35-70
Total or average	65	70.4	5-100	36.3	5-85	54.7	0-100	32.0	0-90

[1]Means followed by the same letter or letter plus subscript differ significantly--a, at 10-percent probability level; b, 5-percent; and c, 1-percent.

Table 5—Average and range of stocking by forest type in Dead Indian and Butte Falls clearcuts

Area and forest type	Sample plots	Regeneration class[1]							
		All		Advance		Subsequent		Second-year	
		Average	Range	Average	Range	Average	Range	Average	Range
	Number	Percent stocking							
Dead Indian:									
White fir	9	43.3b	20-75	3.3	0-15	41.7b	10-70	2.8	0-15
Douglas-fir	7	19.3b	0-40	5.0	0-25	16.4b	0-40	1.4	0-10
Total or average	16	32.8	0-75	4.1	0-25	30.6	0-70	2.2	0-15
Butte Falls:									
White fir	5	81.0a	75-90	7.0	0-25	80.0b	75-90	2.0	0-5
Douglas-fir	6	68.3a	55-90	10.0	0-30	65.8b	50-80	4.2	0-10
Total or average	11	74.1	50-90	8.6	0-30	72.3	50-90	3.2	0-10
Dead Indian and Butte Falls:									
White fir	14	56.8	20-90	4.6	0-25	55.4	10-90	2.5	0-15
Douglas-fir	13	41.9	0-90	7.3	0-30	39.2	0-80	2.7	0-10
Total or average	27	49.6	0-90	5.9	0-30	47.6	0-90	2.6	0-15

[1]Means followed by the same letter differ significantly--a, at 10-percent probability level; and b, 5-percent.

Stocking levels for clearcuts in the white fir and Douglas-fir types were in reverse order to those for partial cuts (table 5). Total stocking and subsequent stocking averaged one-third higher in the white fir type than in the Douglas-fir type. Advance reproduction and second-year seedlings were scarce on clearcuts; levels were too low to interpret for relative differences. Alone or mixed with other species, ponderosa pine had been spot seeded or planted on all but one of the clearcuts sampled. Differences resulting from species mix, reforestation method, and spacing prevent clear identification of the effects forest type had on regeneration establishment.

Even though there are demonstrated statistical differences in average stocking among forest types and more could be proved at probability levels over 10 percent, it is important to recognize that stocking ranged widely among plots in every type (tables 4 and 5). It varied less in the Butte Falls area than in Dead Indian.

Stocking by Soil Type

Sample plots were sorted by soil type, and the stocking averages for the four classes of regeneration were then determined as for forest type. Plots were even less uniformly distributed among soil types than among forest types. In the Butte Falls area, soil series were represented by plots that were geographically well dispersed; in the Dead Indian area, seven of eight plots on soil series 810 were located in the easternmost part—ranges 5 and 6, Willamette meridian. Most plots on other Dead Indian soils were located in ranges 2, 3, and 4.

Total and subsequent stocking seems to be slightly higher on soil series 810 than on other soil series, but such differences were statistically confirmed only for subsequent stocking at Butte Falls (tables 6 and 7).

Since soil series 810 has depth and other characteristics intermediate to soil series 750 and 809, its characteristics are not likely to be unique enough to differentially influence stocking level. More likely, geographic location, forest type, and other factors associated with this soil are contributing influences. Because both soil development and its classification are linked with such primary environmental variables as slope, aspect, and precipitation, analyzing data for associations between stocking and these environmental variables is more direct and more likely to prove rewarding.

Table 6—Average and range of stocking by soil series in Dead Indian and Butte Falls partial cuts

Area and soil series	Sample plots	Regeneration class[1]							
		All		Advance		Subsequent		Second-year	
		Average	Range	Average	Range	Average	Range	Average	Range
	Number	Percent stocking							
Dead Indian:									
809	30	64.7	10-100	33.3	5-75	51.5	5-95	36.3	5-80
810	7	71.4	35-100	46.4	10-85	47.9	0-75	30.0	5-70
840	2	70.0	60-80	27.5	5-50	52.5	50-55	22.5	5-40
850	1	5.0	-----	5.0	-----	0	-----	45.0	-----
882	4	70.0	45-85	40.0	25-50	53.8	30-70	35.3	15-65
Total or average	44	65.1	10-100	35.1	5-85	50.0	0-95	34.9	5-80
Butte Falls:									
740	3	76.7	55-100	$55.0b_2$	45-70	31.7bc	5-55	23.3	10-30
750	11	79.1	50-100	$44.1b_1$	20-75	65.0b	35-100	26.4	0-90
810	7	87.1	60-100	$23.6b_1b_2$	5-55	77.9c	50-95	26.4	0-65
Total or average	21	81.4	50-100	38.8	5-75	64.5	5-100	26.0	0-90
Dead Indian and Butte Falls:									
810	14	79.3	35-100	35.0	5-85	62.9	0-95	28.2	0-70

[1] Means followed by the same letter or letter plus subscript differ significantly--b, at 5-percent probability level; and c, 1-percent.

Table 7—Average and range of stocking by soil series in Dead Indian and Butte Falls clearcuts

Area and soil series	Sample plots	Regeneration class[1]							
		All		Advance		Subsequent		Second-year	
		Average	Range	Average	Range	Average	Range	Average	Range
	Number	Percent stocking							
Dead Indian:									
809	15	30.0	0-70	3.3	0-25	28.0	0-70	2.0	0-15
810	1	75.0	--	10.0	--	70.0	--	5.0	--
Total or average	16	32.8	0-75	4.1	0-25	30.6	0-70	2.2	0-15
Butte Falls:									
750	10	75.5	55-90	9.5	0-30	73.5	50-90	3.5	0-10
810	1	60.0	--	0	--	60.0	--	0	--
Total or average	11	74.1	55-90	8.6	0-30	72.3	50-90	3.2	0-10
Dead Indian and Butte Falls:									
810	2	67.5	60-75	5.0	0-10	65.0	60-70	2.5	0-5

Stocking by Location

Stocking in Dead Indian partial cuts differed significantly by geographic location. Total and subsequent stocking were lowest for plots in T.39 S., R.3 E., yet stocking with second-year seedlings was substantially above average (table 8). In adjacent townships to the north and northeast, total stocking was about average, and in all other townships it was above average. Subsequent stocking was well below average only in T.39 S., R.3 E. Seven of the 9 sample plots with less than 30-percent subsequent stocking were located in this township; of those with less than 50-percent subsequent stocking, 9 of 18 were in this township.

Clearcuts in T.38 S., R.4 E. had substantially less total and subsequent stocking than those in the adjacent township to the west (table 9). In all, 12 of 16 clearcuts in the Dead Indian area had less than 50-percent stocking.

In the Butte Falls area, partial cuts in T.34 S., R.3 E. had significantly lower stocking of subsequent regeneration than in T.33 S., R.2 E., but higher stocking of advance regeneration. Clearcuts in T.33 S., Rs. 2 and 3 E. had the lowest total and subsequent stocking.

On a drainage basis, total stocking averaged highest for partial cuts and clearcuts located in the eastern part of Dead Indian—in upper side drainages grouped as Klamath River (tables 10 and 11). The next highest averages were for cuttings in Little Butte Creek flowing from the northwest part of Dead Indian to the Rogue River. Total stocking averaged lowest in Jenny Creek and Bear Creek, which drain most of the western and central parts of the Dead Indian area and flow to the Klamath and Rogue Rivers, respectively. Subsequent stocking also tended to be higher in the Klamath River and Little Butte Creek drainages than in the Jenny and Bear Creek drainages.

Table 8—Average stocking by township in Dead Indian and Butte Falls partial cuts

Area and township	Sample plots	Regeneration class[1]			
		All	Advance	Subsequent	Second-year
	Number	Percent stocking			
Dead Indian:					
T. 38 S., R. 3 E.	6	62.5	24.2	53.3	26.7ab
T. 38 S., R. 4 E.	7	59.3a	31.4	48.6	18.6c_2c_3
T. 38 S., R. 5 E.	5	84.0ab	41.0	72.0c	48.0ac_1c_3
T. 38 S., R. 6 E.	3	75.0	46.7	51.7	8.3a_1cc_1
T. 39 S., R. 3 E.	14	50.4a_1b	27.1a	32.5ac	50.7a_2b_1cc_2
T. 39 S., R. 4 E.	5	74.0a_1	47.0a	58.0a	34.0a_1a_2
T. 39 S., R. 5 E.	2	87.5	42.5	80.0	12.5
T. 39 S., R. 6 E.	1	100.0	85.0	70.0	70.0
T. 40 S., R. 2 E.	1	80.0	50.0	50.0	5.0
Total or average	44	65.1	35.1	50.0	34.9
Butte Falls:					
T. 33 S., R. 2 E.	5	85.0	27.0a_1	77.0a	31.0
T. 34 S., R. 2 E.	3	86.7	23.3$_a$	68.3	21.7
T. 34 S., R. 3 E.	7	72.1	50.7aa_1	51.4a	25.7
T. 35 S., R. 2 E.	5	86.0	46.0	63.0	16.0
T. 36 S., R. 2 E.	1	90.0	25.0	90.0	65.0
Total or average	21	81.4	38.8	64.5	26.0

[1]Means followed by the same letter or letter plus subscript differ significantly--a, at 10-percent probability level; b, 5-percent; and c, 1-percent.

Table 9—Average stocking by township in Dead Indian and Butte Falls clearcuts

Area and township	Sample plots	Regeneration class[1]			
		All	Advance	Subsequent	Second-year
	Number	Percent stocking			
Dead Indian:					
T. 38 S., R. 3 E.	10	35.5	2.0	34.5a	2.0
T. 38 S., R. 4 E.	5	19.0	7.0	15.0a	2.0
T. 38 S., R. 6 E.	1	75.0	10.0	70.0	5.0
Total or average	16	32.8	4.1	30.6	2.2
Butte Falls:					
T. 33 S., R. 2 E.	1	55.0	5.0	50.0	10.0
T. 33 S., R. 3 E.	2	62.5	2.5	62.5	5.0
T. 34 S., R. 2 E.	1	90.0	30.0	80.0	0.
T. 34 S., R. 3 E.	6	78.3	7.5	77.5	2.5
T. 35 S., R. 2 E.	1	75.0	10.0	75.0	0.
Total or average	11	74.1	8.6	72.3	3.2

[1]Means followed by "a" differ significantly at the 10-percent probability level.

In Butte Falls, the higher average total and subsequent stocking for partial cuts in Little Butte Creek did not prove statistically significant at the 10-percent level. Among clearcuts, the averages were significantly higher in the Big Butte Creek drainage than in areas draining directly into the Rogue River.

Table 10—Average stocking by drainage in Dead Indian and Butte Falls partial cuts

Area and drainage	Sample plots	Regeneration class[1]			
		All	Advance	Subsequent	Second-year
	Number	Percent stocking			
Dead Indian:					
Klamath River	8	80.6b	47.5b	61.3	31.9
Jenny Creek	31	62.1b	34.2	47.3	36.6
Little Butte Creek	3	70.0	16.7b	65.0	31.7
Bear Creek	2	42.5	27.5	25.0	25.0
Total or average	44	65.1	35.1	50.0	34.9
Butte Falls:					
Rogue River	7	80.7	35.0	65.0	24.3
Big Butte Creek	11	79.1	44.1	60.0	25.0
Little Butte Creek	3	91.7	28.3	80.0	33.3
Total or average	21	81.4	38.8	64.5	26.0

[1]Means followed by "b" differ significantly at the 5-percent probability level.

Table 11—Average stocking by drainage in Dead Indian and Butte Falls clearcuts

Area and drainage	Sample plots	Regeneration class[1]			
		All	Advance	Subsequent	Second-year
	Number	Percent stocking			
Dead Indian:					
Klamath River	1	75.0	10.0	70.0	5.0
Jenny Creek	7	21.4a	5.7	18.6a	1.4
Little Butte Creek	7	40.0a	2.1	38.6a	2.1
Bear Creek	1	20.0	0.	20.0	5.0
Total or average	16	32.8	4.1	30.6	2.2
Butte Falls:					
Rogue River	4	61.3c	5.0	60.0c	6.3b
Big Butte Creek	7	81.4c	10.7	79.3c	1.4b
Total or average	11	74.1	8.6	72.3	3.2

[1]Means followed by the same letter differ significantly--a, at 10-percent probability level; b, 5-percent; and c, 1-percent.

Tests for Associations

Data on 15 environmental variables were used in both correlation and regression analyses to ascertain stocking patterns in partial cuts. The independent variables or covariates are listed below; data source and pertinent details on most are given in the appendix.

1. Elevation (feet)
2. Average annual precipitation (inches)
3. Aspect index
4. Average slope (percent)
5. Radiation index
6. Canopy (percent)
7. Time since logging (years)
8. Total ground cover (percent)
9. Ground cover primarily grass (percent)
10. Ground cover primarily woody perennials (percent)
11. Seedbed primarily duff and litter (percent)
12. Seedbed primarily logs, wood, and bark (percent)
13. Seedbed primarily undisturbed, variables 11 and 12 combined (percent)
14. Nearest seed source Douglas-fir (percent)
15. Nearest seed source true firs (percent)

Thirteen variables were used for analyses of stocking patterns in clearcuts. Distance to seed source was substituted for variables 14 and 15 above, which give seed source proximity for only two individual species. Although some canopy was present on clearcuts, variable 6 was deleted because it represented a severe mix of independent and dependent variables—residual trees plus high brush and regeneration that developed after logging.

Variables 9 to 15 result from classifying the 20 subplots per plot in different ways. For example, variables 9 and 10 are fractions (each expressed as a percent of 20) of a four-way classification—without cover, grass cover, herbaceous cover, or woody perennial cover. Not all parts of such a classification may validly be included in a regression analysis. The specific fractions selected were those that appeared most likely to differ from the rest, had the widest range of data, or were of particular interest.

Sufficiently comprehensive regeneration data were available on Dead Indian and Butte Falls partial cuts and clearcuts for these dependent variables:

1. Total stocking
2. Advance stocking, all species
3. Advance stocking, Douglas-fir
4. Advance stocking, true firs
5. Advance stocking, incense-cedar
6. Subsequent stocking, all species
7. Subsequent stocking, Douglas-fir
8. Subsequent stocking, true firs
9. Subsequent stocking, incense-cedar
10. Second-year stocking, all species

Correlation tests between single independent and dependent variables revealed that in neither the Dead Indian nor the Butte Falls areas is stocking distributed at random. There are variations or patterns of stocking significantly associated with changes in independent environmental variables such as elevation, radiation index, or aspect index; and covariates, such as total ground cover, grass, and woody perennials. Correlations identified as significant for different categories of regeneration in the two areas are listed in appendix tables; only highlights are discussed here.

As a broad generalization for data sets combined from Dead Indian and Butte Falls partial cuts, total stocking tended to increase as Douglas-fir became a greater part of the nearest seed source and woody perennials became a larger part of the ground cover (table 21, appendix). Total stocking tended to decrease as elevation, radiation index, and nearby true fir seed source increased. These broad tendencies appear to have split origins, however, for different associations tested significant in the individual areas. In only three instances did stocking for a regeneration category correlate significantly with the same environmental variable for both Dead Indian and Butte Falls partial cuts.

Likewise, total subsequent stocking correlated with different environmental variables in the Butte Falls and Dead Indian areas (table 22, appendix). In Dead Indian, subsequent stocking tended to be higher as aspect index rose (from SSW to NNE) and woody perennials increased. Subsequent stocking was less at higher elevations, as radiation index rose, and as nearby true fir seed source increased. Negative correlations (lower stocking) in Butte Falls involved increases in canopy, duff and litter, and undisturbed seedbed.

Differences in response to environmental variables seem to be indicated by the varying array of correlations significant for individual species in each geographic area. There are also instances where under different circumstances, stocking of a species correlates in the opposite way with a given variable. For example, stocking of Douglas-fir advance growth tended to increase with an increase in duff and litter, but stocking of subsequent Douglas-fir tended to be less with increases in duff and litter.

In clearcuts, total stocking and total subsequent stocking for areas combined tended to increase with increases in woody perennials, duff and litter, precipitation, and undisturbed seedbed and to decrease as elevation or amount of grass increased (tables 23 and 24, appendix). Again, these broad tendencies had split origins. In only four instances did stocking for a regeneration category correlate significantly with the same environmental variable for both Dead Indian and Butte Falls clearcuts.

Stocking appears to have a reasonably consistent correlation with several environmental variables in both partial cuts and clearcuts. For example, stocking generally decreased as elevation or radiation index increased. (The anomaly—increased stocking of second-year seedlings with increasing elevation—appears attributable to the abundance of Shasta red fir seedlings on a few partial cuts at high elevations.) Stocking was also inversely correlated with grass with only one exception—advance stocking of incense-cedar in partial cuts increased with increases in grass.

Stocking was generally less as total ground cover increased but there were a few exceptions—for subsequent true firs in Dead Indian partial cuts and subsequent incense-cedar in Dead Indian clearcuts. Higher stocking was generally associated with increases in aspect index or in the amount of woody perennials present.

Correlation coefficients between stocking and environmental variables were also determined after data had been regrouped by forest type. Because forest types are identifiable ecologic units that often span several geographic areas, there may be more consistent stocking patterns within a forest type than among the mix of types in a geographic area. Tables 25-28 (appendix) list stocking-environmental variable correlations that tested significant in each forest type for which sufficient stocking data were available.

Correlation coefficients for stocking-environmental associations in partial cuts were generally higher if data were analyzed by forest type than by geographic area (tables 25 and 26 vs. tables 21 and 22, appendix). Correlation coefficients for stocking-environmental associations in clearcuts were similar whether compared by forest type or geographic area (tables 27 and 28 vs. 23 and 24, appendix). This indicates that forest type may be a more useful stratification when one is dealing with regeneration in partial cuts than in clearcuts.

Regeneration patterns in partial cuts differed by forest type, as indicated by the dissimilar number and array of correlations found significant per type (tables 25 and 26, appendix). Stocking of advance regeneration was strongly associated with many environmental variables in the Douglas-fir type, substantially fewer in the white fir and pine types. Though still dissimilar, the number of significant associations for subsequent regeneration were nearly equal among forest types.

Some stocking-environmental associations in partial cuts were common to several regeneration categories or forest types. Not unexpectedly, stocking of advance regeneration increased with increases in duff and litter, canopy, and undisturbed seedbed—conditions requisite to or arising from the presence of advance growth. Stocking of advance growth generally tended to be negatively correlated with increases in elevation, true fir seed source, aspect index, total ground cover, grass, and radiation index. Stocking of subsequent regeneration generally increased with increases in Douglas-fir seed source, aspect index, and precipitation, and tended to be less with increases in elevation, undisturbed seedbed, duff and litter, true fir seed source, grass, and radiation index.

For clearcuts, neither the total number nor the array of significant stocking-environmental variable associations were as dissimilar among forest types as in partial cuts. A surprising portion of all environmental variables accounted individually for more than half the variation found in stocking of advance or subsequent regeneration (tables 27 and 28, appendix). Furthermore, stocking was consistently correlated negatively with only two variables—elevation and grass. Among significant variables common to both clearcuts and partial cuts, stocking usually correlated negatively with increases in total ground cover, grass, radiation index, and elevation.

Formulas Describing Stocking

Although an examination of correlation coefficients provides insight on association between paired independent and dependent variables, information is also needed to show how several variables are interacting. For this purpose, stepwise multiple regression analyses were made with data for the environmental variables and regeneration categories already itemized (p. 21). Analyses were made with data sets singly and combined for Dead Indian and Butte Falls partial cuts, and for Dead Indian and Butte Falls clearcuts. Independent variables listed in each formula are generally those which singly had an F value (variance ratio) to enter or remove from the equation equal to or greater than the critical value of the F distribution at 0.10. Occasionally a variable with a smaller F value was included because of its position within the array of qualifying variables or its contribution to the cumulative R^2 (coefficient of determination), provided the total number of variables remained reasonable for the size of the data base.

The analyses produced for the 10 regeneration categories statistically significant multiple regression formulas relating the variation of existing stocking to changes in one or more environmental variables. Formulas for Dead Indian partial cuts are listed in table 29 (appendix); for Butte Falls in table 30 (appendix). All regressions for Dead Indian partial cuts but one account for less than half the total variation in stocking; for Butte Falls all but one account for more than half the variation. Perhaps random variability is greater, or unmeasured variables are influencing stocking more in Dead Indian than in Butte Falls, since over twice as many samples were taken in the Dead Indian area (44 vs. 21).

Combining data from Dead Indian and Butte Falls partial cuts did not produce better regressions. In six formulas, the amount of variation accounted for was only equal to or less than by formulas for the areas singly, and in the other four the cumulative R^2 was intermediate (tables 29, 30, and 31, appendix). Moreover, few of the environmental variables in regressions for Dead Indian partial cuts appear in the equivalent regressions for Butte Falls. Thus, the regression formulas, as well as the stocking, environmental, and correlation data, amply demonstrate that regeneration conditions differ greatly in Dead Indian and Butte Falls partial cuts.

In all but two instances, multiple regressions statistically significant at the 5-percent probability level or higher related the variation of stocking in clearcuts to changes in one or more environmental variables (tables 32 and 33, appendix). Significance of the regressions for all advance stocking and for incense-cedar advance stocking in Dead Indian clearcuts was at the 10- and 10- to 25-percent probability levels, respectively. The amount of stocking variation accounted for is

quite high; only regressions for advance stocking in Dead Indian clearcuts account for 50 percent or less of the total variation.

Again, combining Dead Indian and Butte Falls data did not prove fruitful. In six formulas the stocking variation accounted for was less, and in the other four the cumulative R^2 was intermediate (tables 32, 33, and 34, appendix). Also, few of the environmental variables are common to Dead Indian and Butte Falls regressions. As with partial cuts, regeneration conditions clearly differ in Dead Indian and Butte Falls clearcuts.

Regression equations describing stocking-environmental relationships in partial cuts fit better when the data are grouped by forest type (tables 35, 36, and 37, appendix) than by geographic area (tables 29 and 30, appendix). Quality of fit was judged by summing R^2 values for sets of equations and comparing the average variation accounted for per equation.[4] On the average, equations based on geographic area accounted for 48.5 percent of the variation in stocking; those based on forest type, 59.5 percent. This difference seems important since it arises primarily from regrouping of the same data. Only the two plots in the Shasta red fir type are represented in the geographic grouping and not in the forest type grouping.

In the Douglas-fir and pine types, the stocking-environmental relationship for every regeneration category is described by a strong regression equation—one that with two to five variables accounts for over half the total variation in stocking (tables 35 and 37). Judged by the same criterion, regressions describing relationships in the white fir type are weak (table 36). All but two account for less than half the total variation in stocking. It appears that stocking has less pattern in the white fir type, or it is not strongly patterned by the observed environmental variables.

[4]Direct comparison of R^2 values for equations within each stocking category is not possible because for forest types the categories include data from both the Dead Indian and Butte Falls areas.

Grouping data by forest type (tables 38 and 39, appendix) instead of geographic area (tables 32 and 33, appendix) did not change the average fit of regressions for stocking-environmental relationships in clearcuts as it did for partial cuts. The difference in cumulative R^2, however, was usually less between equations of the same regeneration category in the two forest types than in the two geographic areas. Such evidence suggests that stocking variations in clearcuts are also best considered in the context of forest type.

Predicting Regeneration

Preceding sections of this report have shown how present stocking associates or changes with observed environmental variables. But such variables as total ground cover, woody perennials, and grass are covariates. They may be absent or of minor consequence at harvest and increase just as tree stocking does with time. For assessing reforestation possibilities before an area is cut, it would be useful to know how prevailing environmental variables, plus those whose levels are regulated by the harvest, influence subsequent regeneration. So prediction equations were developed for subsequent stocking based on environmental variables that can be observed or specified before harvest. Eleven variables—elevation, radiation index, aspect index, slope, canopy, duff and litter, logs and bark, Douglas-fir seed source, true fir seed source, precipitation, and undisturbed seedbed—were used in analyses for partial cuts. Nine variables were used in analyses for clearcuts; canopy, Douglas-fir seed source, and true fir seed source were deleted from the preceding group, and seed source distance was added.

Similar prediction equations for advance regeneration are not needed since the amount present at harvest or immediately after can and should be measured directly.

Prediction equations based on forest types (tables 40 and 41, appendix) appear preferable to those based on geographic area (tables 42 and 43, appendix). Reasonably comparable amounts of the total variation are accounted for by the sets of equations, but those for forest type probably have broader applicability. The origin of a forest type and its perpetuation is directly related to the mix of environmental conditions that prevail. Hence, stocking—environmental relationships found important in one part of a type could reasonably be expected to prevail broadly throughout the type.

In general, more of the total variation is accounted for by prediction equations for clearcuts than those for partial cuts. The equations for clearcuts in the Douglas-fir type and for partial cuts in the pine type are particularly strong; no more than three variables account for over half the total variation in all equations but one. Equations for second-year stocking tend to be weaker than most others, but are also the ones least likely to be needed. Equations for total subsequent regeneration are probably the most useful because they include the response of all species; for clearcuts in particular, they reflect the large influence of planted ponderosa pine which is not in the other equations.

Forest Management Applications

A comprehensive analysis of reforestation status and relationships provides first approximations for management and serves to clarify or pinpoint problems that need to be solved. The broad implications of study results are emphasized in these interpretations; mention of how results relate to reforestation principles observed elsewhere are mostly incidental.

Silvicultural Units

The Dead Indian and Butte Falls areas differ in geography, climate, forest communities, and reforestation response. Perhaps results of this study bring area differences into focus more comprehensively than ever before. By and large, the territory sampled around the town of Butte Falls is mid-elevational, the 25 to 50 inches (64 to 127 cm) of rainfall is conducive to forest growth, and growing conditions probably do not differ greatly from other mid-elevation locations farther north in the Rogue River and Umpqua drainages. In contrast, Dead Indian is primarily an upper slope area. The lower end of its 18- to 40-inch (46- to 102-cm) rainfall range approaches the margin for commercial tree growth, and growing conditions are more varied and limited. Because of these contrasts, foresters should logically draw from quite different geographic sources for research results and silvicultural experiences that might apply in the Dead Indian or the Butte Falls area.

Study results clearly demonstrate that the environmental differences between the Butte Falls and Dead Indian areas influence reforestation response. In Butte Falls, the stocking is greater, species mix richer, understory development more dense, and the array of factors that correlated with stocking different than for Dead Indian. Moreover, stocking patterns were described best by regressions when data for the two areas were used separately. Identical silvicultural practice is not likely to produce the same result in both areas, and management must recognize area individuality to a greater degree than in the past.

A line or band marking the silvicultural division between Butte Falls and Dead Indian territory needs to be delineated. Currently, both names apply to loosely defined geographic areas. For study purposes, a common boundary was arbitrarily drawn northeast of Ashland (fig. 1). Dead Indian and Conde Creeks, upper drainages that actually flow toward Butte Falls, were included as part of the Dead Indian area. Because of cutover distribution, nearest sample plots of the two areas were separated by a dozen miles (19 km) or more. Somewhere within that span or near its southern edge, a logical silvicultural demarcation should be made.

Elevation, drainage system, or changes in understory community might be used as the basis for this demarcation. There are distinct differences between the two areas in the occurrence of woody perennials and the mix of species in the understory. The delineation could be based on shrub differences observed in this study, or on the detailed vegetation information developed by Minore and Carkin[5] (1978). In a historical summary, Minore (1978) delineated the Dead Indian area's northern limit as the precipitous slopes above (south) of Little Butte Creek.

For intensive application of silvicultural and reforestation practices, recognition of subdivisions within each territory also appears necessary. Forest type seems to be a practical and readily available initial subdivision. Stratification by forest types might prove very useful because these are identifiable ecologic entities whose characteristics and response may be similar in several geographic areas. Types reflect site, elevation, and successional differences that affect reforestation. Eventually, reforestation responses should be related specifically to plant communities or habitat types.

[5] Minore, Don, and Richard E. Carkin. 1975. Relation of environmental factors to regeneration after partial cutting in the Dead Indian Plateau and Butte Falls areas of southwestern Oregon—A report to the Bureau of Land Management. 18 p. Unpublished report on file at the Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Interpreting Stocking Data

Stocking values generally express actual stocking as a percent of full stocking. Consequently, full stocking must be defined before the true significance of observed stocking values can be assessed. By agreement among participants at the start of this study, full stocking was set at 250 uniformly distributed trees per acre. This standard can be met if one countable tree is present on every 4-milacre subplot examined.

In the stocked quadrat sampling system, only one countable tree must be present for a 4-milacre plot to be stocked (Stein 1978). Hence, a stocking value of 50 percent means that at least 125 well-distributed trees are present per acre (310 per ha). The system produces a minimum figure; it is strongly oriented toward evaluation of tree distribution, not total numbers. Where trees are uniformly distributed as in a plantation, stocking may closely reflect the total number present—not so for natural regeneration or mixes of artificial and natural regeneration. In natural regeneration, 50-percent stocking might mean nearly 400 trees per acre (990 per ha); 85-percent stocking over 1,200 (2 965 per ha) (Bever and Lavender 1955). The conversion curves used in this example were developed from data for natural regeneration in western Oregon clearcuts and may not be fully applicable in partial cuts. The comparisons indicate, however, what stocking data mean in terms of total trees per acre.

If stocked and nonstocked plots are well interspersed, 50-percent stocking can produce a good stand. If they are not, part of the sampled area will be well stocked or overstocked and part of the area will be short of trees.

Regeneration in Partial Cuts

Throughout this paper, forest stands from which some overstory had been removed through harvest have been called partial cuts, not shelterwoods. This was done deliberately because many partially cut stands did not qualify as shelterwoods in the full technical sense of that term. Instead,

they were the product of an initial cut in virgin old-growth forest of varied composition, density, age class, and size. Many stands had an open overstory for a long time before harvest which fostered advance regeneration. Some stands were cluttered with overly dense advance regeneration, others with more uniform and heavy canopy were relatively bare underneath. Thus, stocking data reflect the regeneration present in a wide range of stand conditions rather than in uniform stands whose nature can be defined readily.

The partial cutting done in both Butte Falls and Dead Indian stands between 1956 and 1970 has been referred to as a "three-stage shelterwood." A first cut to open up the stand is to be followed by a second cut in 10 years and a final cut in another 10 years. The second cut is intended to foster regeneration. According to the records, only 9 of the 44 stands sampled in Dead Indian and none of those sampled in Butte Falls had received a defined regeneration cut. Stocking of seedlings that established after harvest on areas entered twice averaged 56 percent but included one area with only 5-percent stocking. Canopy on these areas averaged 41 percent, similar to the 44-percent average for all samples. They were not considered sufficiently different from areas entered only once to warrant separate summary and analysis.

Achievement of a specified basal area, composition, or distribution of overstory did not appear to have been among primary objectives for the first cut. In some stands, scattered single trees had been removed, leaving a reasonably uniform and rather dense overstory; in others, small clearings were interspersed with nearly unthinned canopy (fig. 16). Some stands were opened up drastically; 10 sampled in Dead Indian had 30-percent canopy or less. A good choice of seed trees was readily evident in some areas; in others, the adequacy of the remaining seed source was much in doubt. In summary, the stands sampled had a large amount of initial variability, were not necessarily made more uniform by the first cut, and most were sampled before the second or "regeneration" cut had been made.

Figure 16.—Partial cuts included stands with small clearings and adjacent, unthinned canopy.

Even though sampling occurred before the "regeneration" cut, substantial regeneration was found in partial cuts. In fact, only one-fourth of the areas sampled in Dead Indian and none of those sampled in Butte Falls were less than 50 percent stocked with 2-year or older regeneration. If stocking were the sole criterion, the regeneration already present could be rated satisfactory in most partial cuts. Such is not the case, however.

In enough instances to cause concern, seedling growth was very slow. There also was evidence that successive crops of new seedlings are not developing as needed for projected timber production. Field notes for about one-quarter of the Dead Indian plots include comments on the lack of seedling vigor or height growth; good vigor or growth is mentioned for about an equal number. Excerpts from the notes illustrate concerns about growth:

Seedlings have fair to poor health; most are shaded and on rotten wood.

Seedlings found along roadsides were healthier than those in the plot.

Seedlings were tallest in areas where competition was lowest; many seedlings were found on roadbanks and other exposed sites.

This area has been available for seedling establishment for 10 years; but there is a scarcity of seedlings more than 2 years old . . . the largest seedlings were found on some of the more open subplots.

Reproduction is fairly abundant, but most of it is too small for age of the cutting.

Slow growth of seedlings was also noted in some Butte Falls partial cuts; better growth on disturbed than on undisturbed seedbeds was specifically recorded several times.

In many partial cuts, seedling growth must be accelerated to achieve meaningful development. Some obstacles to overcome are discussed in the section, Problems to Solve.

Role of Advance Regeneration

The abundant regeneration often present before harvest begins provides opportunities that have hardly been exploited. The magnitude of these opportunities is highlighted by study data which show that, after harvest, 31 percent of all partial cuts were at least 50 percent stocked with advance regeneration. Before harvest, even more areas might have been stocked at or above that level. Not all advance regeneration has crop tree potential, but many trees do. The stand establishment period may be bypassed and a long step taken into the next rotation if adequate advance regeneration can be protected during a relatively short conversion period.

Efforts to save advance regeneration were evident in some partial cuts; in others, destruction of prime saplings and poles during logging was excessive. Often the pattern of overstory removal was less than optimum for release of advance regeneration. Furthermore, an arbitrary 10-year reentry cycle does not meet the silvical needs of stands with abundant advance regeneration. Complete removal of scattered overstory is desirable in the first cut when an area is already adequately stocked. Felling and skidding direction should be controlled to minimize damage during removal of overstory from regeneration thickets where it no longer serves a useful purpose. Most terrain in Dead Indian and Butte Falls is gentle enough to permit the maneuverability needed to save advance growth.

Some partial cuts were overstocked. Perhaps 43 percent of those in Butte Falls were, since 90-percent stocking of natural regeneration might average 1,400 trees per acre (3 460 per ha) (Bever and Lavender 1955). Some of the poor growth noted was due to excessive numbers of saplings. Since numerous new seedlings are also becoming established in partial cuts, additional areas will soon become overstocked. Adequacy of regeneration should be assessed periodically so that overstory is removed on a timely basis, seedling accretion is halted, and the new stand is fully released.

Only a few instances of exposure damage were observed on advance regeneration released from overstory. Frost occurs in some locations, and newly exposed stems may sunscald. Situations where these dangers exist need to be identified. Where overexposure is not a problem, growth could often be enhanced by thinning advance regeneration as soon as it has stabilized after release.

Overstory mortality from exposure, growth rate of residual trees and stands, spread of mistletoe from mature trees to regeneration, damage caused by successive entries, and other factors are important elements of a decision to foster regeneration through use of shelterwood. Their evaluation was not within the scope of this study.

Regeneration in Clearcuts

The reforestation methods used in Butte Falls clearcuts produced moderate stocking or better in every area sampled; in Dead Indian clearcuts only 1 in 4 was as satisfactory (fig. 8). Early reforestation attempts involved much trial and error, and the records show distinctly different sequences were tried in Butte Falls and Dead Indian clearcuts. In Butte Falls, slash was spot-burned (sometimes broadcast-burned) and the clearcut was generally spot-seeded the same year or planted the next year. Required replanting was usually done a year or two after the initial reforestation effort. Clearcuts in Dead Indian were also spot- or broadcast-burned, but then a lengthy period was allowed (averaging more than 4 years) for establishment of natural regeneration. Every clearcut was planted eventually, over half more than once. How often and what kind of site preparation accompanied delayed planting is uncertain. All reforestation delays permitted development of competing vegetation and buildup of animal populations. Consequently, tree establishment was made more difficult than if clearcuts had been planted at the first opportunity.

The reputation of Dead Indian as a reforestation problem area is based largely on the repeated failure of reforestation efforts in a small number of old clearcuts and burns. Results on such areas may not be similar to those on fresh clearcuts and certainly do not represent best application of modern reforestation technology. When assessing the difficulty of reforesting clearcuts, it is critically important to examine all available evidence.

Study results definitely show that under past reforestation practices, establishment of natural regeneration was not adequate in either Butte Falls or Dead Indian clearcuts. Those practices generally included laying out the clearcut in a rectangular block, burning some slash, letting grass develop, and permitting unrestricted grazing. Gopher activity has often been heavy and control efforts limited. To some extent, the cover of woody perennials under which natural regeneration might start has been held in check, particularly in Dead Indian clearcuts, by grazing and gophers and sometimes by scarification or herbicide spraying. Repeatedly, field notes for plots in both Dead Indian and Butte Falls clearcuts included the observation that natural regeneration was found around logs or under brush cover. It appears such regeneration benefited by protection from sun, frost, and cattle trampling. Instances where good stocking of natural regeneration was found for some distance north of a timber edge were also noted. Plentiful natural regeneration can be observed in the Dead Indian area on exposed roadbanks, particularly along the Keno access road, in several incidental clearings, and near Howard Prairie reservoir (fig. 17). These examples demonstrate that there are circumstances where natural regeneration, even of Douglas-fir and white fir, establish adequately in bare openings. The conditions would have to be defined more specifically, however, before natural regeneration could be relied on to restock such openings. Gentleness of the terrain would certainly permit the use of strip clearcuts or other modified clearings.

Most regeneration found in both Butte Falls and Dead Indian clearcuts originated as planted nursery stock.

Figure 17.—Natural regeneration established abundantly on north slopes in a narrow clearing near Howard Prairie Reservoir.

Ponderosa pine was the main species planted. In a few instances, Jeffrey pine, Douglas-fir, white fir, or Shasta red fir were planted or seeded. Without question, clearcuts in Butte Falls can be adequately reforested by planting ponderosa pine. So can clearcuts in Dead Indian provided the plantations are established promptly and given reasonable protection from cattle and gophers. The advisability of establishing plantations heavily dominated by ponderosa pine is discussed later under Species Composition.

Frost occurrence during the growing season is not uncommon in parts of the Dead Indian area. If fully exposed, such nonhardy species as Douglas-fir and white fir may be killed outright or repeatedly set back by untimely frosts. Even such hardy species as ponderosa pine, lodgepole pine, and Jeffrey pine are damaged occasionally but not as severely (Stein 1963, Williamson and Minore 1978). Frost occurrence varies by topographic location and is much less frequent under forest cover than in the open (Williamson and Minore 1978). Successful establishment of nonhardy species in clearcuts requires knowing where frost is uncommon during the growing season.

Judged by the scope of information on record, the clearcut and plant reforestation system has not received enough prudent trials in either the Dead Indian or Butte Falls area. In Dead Indian particularly, most clearcuts were located on gentle terrain not far from open meadows and old homesteads. Such clearcuts served as extensions of natural meadows in frost pockets that had been heavily grazed for decades (Minore 1978). From the start, above average reforestation difficulty could be expected in such locations. Moreover, timeliness of planting, kind and quality of stock, and plantation tending are all much improved today compared with the technology applied over 15 years ago. Widespread use of clearcutting is not advocated now except for regeneration of ponderosa pine. But judicious tests of clearcutting in selected locations and stands seems desirable since there is good evidence that some cleared areas reforest readily. Well-planned comparisons of silvicultural systems are also needed to demonstrate the results possible by alternate means. Prompt planting and sustained tending of plantations should be an integral part of all future harvest-cutting trials.

A

B

Figure 18.—Because of location or individual differences, growth potential of one ponderosa pine is excellent (**A**) and for the other nil (**B**) in the same clearcut.

Species Composition

True firs, primarily white fir, are now the dominant regeneration by a wide margin in Dead Indian partial cuts and a major component in Butte Falls partial cuts (fig. 13). Continued light partial cutting will foster white fir's already dominant role in the next rotation, for it is the climax species in, and perhaps beyond, the present white fir type. Instances were noted where Douglas-fir regeneration was not proportionate to the seed source present —where the ground was covered with Douglas-fir cones, yet few Douglas-fir seedlings were found. Pine regeneration also did not appear proportionate to the available seed source, whereas incense-cedar regeneration seemed relatively abundant wherever there was any source of seed. It is likely that seedeaters feed more heavily on Douglas-fir and pine seed than on seed of other tree species. There may also be a tendency to cut first the scattered Douglas-firs and pines since these are often older, larger, and of higher quality than the white firs. Whatever the reasons, white fir regeneration is pre-eminent. Should or must management settle for the kind of forestry implicit when the climax species establishes naturally and develops slowly under its own heavy shade? What are feasible alternatives? Will more open, uniform stands or stands with interspersed small openings foster natural or artificial establishment of other species and provide faster growth?

Ponderosa pine is dominant now in clearcuts. With a head start and fast juvenile growth, it is likely to remain dominant for a long time if the stock used proves suitable for the site. Some seedlings of Douglas-fir, white fir, and other species are filtering in naturally; and in the long run, mixed stands will develop. Ponderosa pine has been planted on several clearcuts where it was absent before, but present in the vicinity. These plantings are vulnerable —the pine may do fine or it may suffer excessive damage from snow or other causes before it reaches commercial size. In specific instances, planted pines were making exceptional growth, yet others on the same area were useless because of snow-caused deformities (fig. 18). Even though

ponderosa pine is native and widespread in Dead Indian and has good characteristics and potential, placing sole reliance on this species appears unwise.

A mix of conifers should be the reforestation goal for much of the Butte Falls and Dead Indian areas. This recommendation takes into account the long-term vegetation trends, the structure of present stands, and the practical objectives of management.

From geologic and ecologic evidence, it has been inferred that massive advances and retreats of forest communities have occurred in the western United States. A pine-oak complex which included most of the species found in the southern Cascades reached its most recent northerly advance during a drier era that ended about 6,000 years ago (Detling 1968). As the climate has become cooler and more moist, conifers are replacing oaks, and boundaries of climax types are changing. Many examples of such type replacement can be seen in both the Butte Falls and Dead Indian areas.

The white fir type is just becoming dominant in many parts of the study areas. Fortunately, the seral species that white fir is replacing are still evident. Scattered, very large Douglas-firs are found in some predominantly white fir stands; scattered sugar pines are common; incense-cedar is found on exposed sites; ponderosa pines are monarchs among white fir and Douglas-fir poles, and they also heavily fringe the open meadows. The containment of wildfire and reduction of grazing in the last 50 years has probably speeded the natural succession to white fir and has allowed development of dense understories.

Management for mixed conifers requires that overstory be opened sufficiently to permit seral species, as well as white fir, to become established and make good growth. Mixed conifer stands can probably be established through natural regeneration, but results may often be slow and uncertain. To achieve intensive forestry, major reliance will have to be placed on planting. The uneven distribution of desired seed trees, the infrequency and untimeliness of seed crops, the need for reforesting prepared sites immediately, and the desirability of controlling species, genetic quality, and tree spacing all dictate that reforestation not be left solely to "Mother Nature." Underplanting of shelterwoods has been practiced for several years in the southern Cascades; preliminary results look good, and careful evaluation of this reforestation technique should soon be made.

Stand Prescriptions

No single harvesting system should be designated as standard for the varied stands of the Butte Falls and Dead Indian areas. Instead, there is need to apply silvicultural practices almost on an acre-by-acre basis. Some stands need to be left alone for awhile to develop, patches of poles need complete release from overstory, and dense stands may need either a salvage cut or a shelterwood cut to foster regeneration. In selected locations, strip clearings or overstory removal in patches may best fit particular stand conditions. The suitability and vigor of prospective leave trees need careful scrutiny to minimize the scattered, unpredictable mortality that follows every harvest entry. Such scrutiny should include a search for mistletoe in the overstory and advance regeneration to prevent perpetuation of infected stands.

The first step in reaching broad forest management objectives is to define specific goals, area by area. The alternatives available to attain the goals should then be considered, and the most suitable one chosen. The technical basis for that choice should be written out. This facilitates review by subject matter specialists; but more important, it provides the vital communication needed to maintain on-the-ground continuity. A written stand prescription forms the basis for action and provides a means for checking progress periodically.

Use of Correlations and Equations

Many correlations and equations are included in this report. These were the basis for some of the conclusions and recommendations, but their inclusion serves another major purpose. They are working tools the silviculturist can use.

The regression equations describe separately, by regeneration category, stocking patterns that may not be discernible when successive stands are viewed. Each equation shows, for a particular area or forest type, the environmental variables that surfaced as most important in the mathematical analysis of the survey data. The variables are listed in order of importance, and the fraction of total variation accounted for (cumulative R^2) is shown. The numerical values are unique to the equation as listed—delete or add one variable and a different set of values applies. The plus and minus signs in the equation do not indicate whether individual variables had a positive or negative influence on stocking; this information is given by the correlation coefficients for single variables.

Neither regression equations nor correlation coefficients identify actual biological cause-effect relationships between environmental variables and stocking. They constitute tests of association—that a dependent variable (stocking) and one or more independent variables are varying in concert, either directly or inversely. Biological inferences may be drawn from associations found significant, provided the basis for a cause-effect relationship has already been established independently; such relationships are not proved just because certain associations are shown to exist.

The correlation coefficients should prove useful in preparing prescriptions for establishment of particular species or species mixes. The sign of its correlation coefficient indicates whether stocking was positively or negatively associated with each environmental variable listed. For example, stocking of subsequent Douglas-fir in Butte Falls was shown to be negatively

associated with increases in canopy, duff, and undisturbed seedbed (table 22, appendix). If the silviculturist wants to favor establishment of Douglas-fir, the prescription for natural regeneration should call for a sparse canopy and good disturbance of seedbed. Perhaps not all applicable, significant variables can be accommodated in a prescription for one species, much less for a mix of species. But by giving attention particularly to associations that are common to more than one species, forest type, or area, the silviculturist has guidance based on past local performance that is much better than guesswork.

In using regressions and correlations, silviculturists must keep in mind limitations of the data base. The data for partial cuts are from stands subjected to one or two entries which left, on the average, about 45-percent canopy. Variability of the original overstory was great, no marking rule was applied systematically, and all regeneration had established naturally. The data for clearcuts are from older areas with a varied history of planting and seeding. Artificial regeneration efforts were often delayed several years. None of the equations reflect what may be possible with the most up-to-date site preparation and reforestation technology, but one might reasonably expect that most of the same variables would have a strong influence.

As in every other forested area, there are reforestation problems to solve in the Dead Indian and Butte Falls areas. These problems loom large locally but need to be viewed in perspective. The forest conditions are not any hotter and drier here than they are farther south where the same types grow in northern California, nor so cold and snow burdened as in more northerly upper slope types. Forests have established in abundance naturally, and, by understanding the influencing variables sufficiently, silviculturists should be able to identify ways to speed and otherwise control the process.

Problems to solve are discussed on the premise that reasonably intensive timber management will be practiced —that timber production is a primary objective. Relative importance of the problems would change markedly if management objectives were substantially different. Two additional premises also influence choice of solutions: (1) When desired, an adequate amount of natural regeneration (or of planted trees) can be saved during removal of the initial overstory or shelterwood, and (2) large-scale harvest-system studies are not the best or quickest way to get the kind of answers needed. Skimpy evidence indicates that stocking of seedlings and saplings is not reduced seriously if overstory removal is carefully planned—18 percent of marked trees in ponderosa pine stands of central Oregon (Barrett et al. 1976); 4 percent of milacre stocking in the ponderosa pine type of northern California (McDonald 1969); and 10 percent of 4-milacre stocking in the mixed conifer type of western Oregon (personal observation).

Overstory Required

Survey results and local experiences indicate that natural and planted regeneration of several species establish better, especially in Dead Indian, under the protection of tree canopy than in the open (Minore 1978, Williamson and Minore 1978). Overstory canopy ameliorates strong sunlight, slows wind movement, and reduces outgoing radiation. On the other hand, overstory competes with regeneration for soil moisture and curtails rate of seedling growth. Thus, it is desirable to retain only sufficient overstory to foster establishment of the desired species. The amount of overstory required for different species and circumstances needs much better definition.

Severe frost during the growing season may be a more widespread cause of regeneration failure than drought, particularly in Dead Indian. Ponderosa pine and incense-cedar predominate in clearcuts and other exposed areas because they are more frost and more drought hardy than Douglas-fir and white fir. In clearings, occurrence of the latter two species under cover and behind logs may be due as much to their need for protection from frost as for protection from trampling by cattle. Damaging frosts have been observed through the years in both the Butte Falls and Dead Indian areas. Evidence of frost damage was noted during the survey, and for Dead Indian, the differential effects under canopy and in problem openings have been quantitatively demonstrated by Williamson and Minore (1978).

How to identify frost hazard areas and determine amount of cover needed are key subjects for research. Forestry and meteorological expertise needs to be pooled to find answers for such questions as:

1. On cool nights during the growing season, how much do temperatures differ at selected heights above open ground on flats, north and south slopes, and ridgetops?

2. How much are nocturnal temperatures modified by different amounts of canopy?

3. How tall must regeneration be in different topographic locations to extend above damaging cold air layers; i.e., when may protective canopy be removed?

4. How severe a frost can different species endure during the growing season without damage?

Preliminary information on frost hazards can be gained by observing the geographic location of past and current damage. An adequate understanding will require a thorough search of applicable literature, use of recording instruments, and experimentation on seedlings. The information developed would have much wider application than just in the Dead Indian and Butte Falls areas.

Preventing Moisture Deficiencies

A mature forest community depletes soil moisture far more than a seedling stand does (Bethlahmy 1962). Consequently, reduction of overstory increases the moisture available for seedling establishment, provided evaporation rates from surface layers do not become excessive or competing low vegetation overly dense. Moisture available to seedlings under different amounts of overstory and with different amounts and kinds of competing vegetation has never been adequately defined. An adverse effect of advance growth on establishment of natural regeneration has been reported (Hall 1963).

Drought has been blamed in the past for regeneration failures in the Dead Indian and Butte Falls areas. The lushness of herbaceous growth under dense canopies, the density of many stands, the tall growth of woody perennials in Butte Falls, and the widespread development of thick grass and elderberry in Dead Indian clearcuts raise questions about the true occurrences of drought. Availability of soil moisture in upper soil layers during the growing season could be checked rapidly by gravimetric methods or neutron probe, and moisture stress levels in seedlings or associated vegetation by pressure bomb readings.

A systematic study of soil moisture would define the locations, soils, and situations where moisture supply is truly the limiting factor in establishment of regeneration. Intensive control of vegetation and other moisture-conserving techniques could then be concentrated where they are needed most.

Grass and Grazing

Despite claims to the contrary, evidence accumulated over the years shows that grass production and tree establishment are usually not compatible (Cleary 1978, Nolan 1978). Propagation of grass is one of the quickest ways to render a site inhospitable to young trees. The ready availability of moisture in grass-free soil and its drastic depletion in grass-covered soil was demonstrated some years ago at one Dead Indian location (Hallin 1968). In this study, correlation tests demonstrated the negative association between grass and tree stocking for all species. A single positive correlation between advance stocking of incense-cedar and grass does not indicate that incense-cedar benefited from it. Rather, it is probably the only species that established in stand openings where grass predominated.

Either from natural dispersal or from sowing, grass has developed abundantly on many Dead Indian and Butte Falls clearcuts. It has also invaded or become thicker in partial cuts. Wherever it occurs, grass has the capability of occupying the site long before natural conifer regeneration is likely to occur. Once a site is lost to grass, establishment of trees requires extraordinary effort. Quick reestablishment of trees is one of the best ways to minimize problems with all competing vegetation.

The adverse effects of grass on tree establishment are compounded by the uncontrolled grazing of livestock. Young seedlings are trampled or loosened, and older seedlings are damaged or broken. Woody perennials that might furnish cover for natural regeneration are often browsed or mauled. The destruction of blue elder (*Sambucus cerulea* Raf.) clumps 10 to 15 feet (3 to 5 m) tall in the fall by livestock that need or prefer this forage is remarkable (fig. 19).

Figure 19.—In Dead Indian, cattle stripped all foliage and fruits from large clumps of blue elder.

Cattle damage in partial cuts was most common in the open white fir stands of townships 38 and 39 south, ranges 3 and 4 east, Willamette meridian. To fully appreciate severity of grazing damage, areas must be observed before and after it has occurred. Two examples illustrate this point:

Example 1.—Plot 24 on Cottonwood Creek in the Dead Indian area was examined on June 26, 1973. It was 30 percent stocked—25 percent with advance true firs located in tight clumps and 5 percent (a single subplot) with subsequent true firs. Stocking of second-year seedlings was also 30 percent, found mainly on subplots with trash and rotten wood. Five years after harvest, the soil was extremely loose on this northeast slope at 5,700 feet (1 740 m), canopy density of 36 percent looked ideal, and the 63-percent herbaceous cover lush and thriving. Looseness of the soil and lack of subsequent regeneration were ascribed to gophers, which were present. Snows had melted only a few weeks before; the soil surface was humpy but untracked by animals.

On September 19, 1973, the plot was revisited to show a technical group an example of a good site where regeneration was not as plentiful as it should be. The primary cause of low stocking was then obvious; all herbaceous cover was gone and most of the area was covered by hoofprints as in a barnyard. The surface soil was now even looser and the plot hardly recognizable (fig. 20).

Example 2.—Plot 76 on Jenny Creek in Dead Indian was examined on June 27, 1973. It was found to be 75 percent stocked—40-percent advance regeneration, mostly true firs, and 65-percent subsequent stocking, all true firs. Second-year seedlings were found on 75 percent of the subplots. Ten years after harvest the soil appeared stable on this gentle north aspect at 5,320 feet (1 520 m), gopher activity was present but not abundant, and vigorous herbaceous cover averaged 63 percent. Canopy averaged 38 percent; most of the regeneration was young and small. Trees a foot (0.3 m) or more tall, commensurate with age of the cutting, were found primarily on a heavily disturbed skidroad and among a few burned logs near roadside.

Figure 20.—Trampling by cattle severely redisturbed an already loose soil in a white fir partial cut.

In September 1976 this area was revisited to view the contrasts in seedling size. Most of the large seedlings observed before were now mauled or gone, and signs of grazing and trampling by cattle were everywhere.

Although regeneration was found on both plots, seedlings were smaller and younger than expected, and the new stand was not developing as it should. Cattle were the primary restrictive influence.

Additional research is not needed to solve many problems involving grass competition and grazing damage. The first step in their resolution is to recognize that grass is commonly very unfavorable for tree establishment and that cattle are damaging regeneration in significant amounts. The next step is to decide if and where tree establishment has priority over grazing. Finally, measures must be taken to control grass wherever necessary and to keep cattle out or closely regulate grazing in reforestation areas until the new tree crop is well established.

Animal Damage

Many parts of Dead Indian and Butte Falls also have high populations of wild animals that affect reforestation. Gopher activity has already been recognized as a problem. The effects of rabbits, deer, and other animals will become more evident as marked trees are examined repeatedly.

Gophers have been depleting stands of young trees in these two areas for many years. One study that demonstrated the protracted nature of seedling losses to gophers was already completed in Dead Indian by the early 1960's (Hermann and Thomas 1963). A comparison of methods to control them by manipulating vegetation was recently completed (Black and Hooven 1977).

Gopher control methods are receiving substantial attention throughout the west, so more local studies are probably not critical. Fast establishment of trees before gopher populations build up will help. Population increases that threaten plantations must be recognized and dealt with on a timely basis.

Stand Ecology

Stand composition in Dead Indian and Butte Falls often differs within short distances. These differences may be due to the happenstances of seed crop occurrence when sites were ready for seedling establishment; or the variations may form patterns that provide clues on species limitations, microsite requirements, and ecological trends.

Knowledge gained from studies of species occurrence and requirements should guide the choice of species for different sites. Such studies could help demarcate geographic areas to be managed primarily for white fir, Shasta red fir, mixed conifers, or ponderosa pine. They might even indicate where blister rust hazard is low. Sugar pine is one of the best growing species in the mixed conifer type and should be perpetuated wherever rust hazard is low, or when resistant natural seedlings or planting stock are available. Some information on stand age and structure was obtained by Minore and Carkin as part of their 1976 field work in the Dead Indian area (Minore 1978).

Growth of Regeneration

Information on growth rate is needed for two important topics that influence choice of reforestation practices: (1) Among advance regeneration, which species and stems have the capability to respond promptly to release and then make normal growth? and (2) What are typical growth rates for regeneration under different densities of canopy? An answer to the first question would identify the advance regeneration worth saving. An answer to the second question would define overstory densities that foster reasonable growth of natural or planted regeneration.

Preliminary information on response of sugar pine seedlings to release in the South Umpqua drainage was developed by Hallin (1959), but information is needed for other species and a range of sites. Such information could be obtained quickly by stem analysis of released trees. Correlations between appearance before release and subsequent response would also be easy to obtain, but several years would be required to observe the response of marked trees.

Acknowledgments

Field work by Alexander Yusha, Bruce G. Nicholson (deceased), Gerald A. Hellinga, and Clayton D. Gosmeyer; data compilation and summarization by Gerald A. Hellinga; and statistical consultation by Floyd A. Johnson and John W. Hazard, all of the Pacific Northwest Forest and Range Experiment Station are gratefully acknowledged. Special thanks to Gerald L. Nilles, Medford District, Bureau of Land Management, who provided effective liaison with District personnel, records, and other pertinent sources of information.

Literature Cited

Barrett, James W., Stanley S. Tornbom, and Robert W. Sassaman.
1976. Logging to save ponderosa pine regeneration: A case study. USDA For. Serv. Res. Note PNW-273, 13 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Bethlahmy, Nedavia.
1962. First year effects of timber removal on soil moisture. Int. Assoc. Sci. Hydro. Bull. 7(2):34-38, illus.

Bever, Dale N., and Denis P. Lavender.
1955. Revised "number of trees per acre" curves. Oreg. State Board For. Res. Note 25, 3 p., illus.

Black, Hugh C., and Edward F. Hooven.
1977. Effects of herbicide-induced habitat changes on pocket gophers in southwestern Oregon. *In* Proc. 29th Annu. Calif. Weed Conf. (Sacramento), p. 119-127.

Cleary, Brian D.
1978. Vegetation management and its importance in reforestation. Oreg. State Univ. For. Res. Lab. Res. Note 60, 4 p., illus., Corvallis.

Day, Frank P. Jr., and Carl D. Monk.
1974. Vegetation patterns on a southern Appalachian watershed. Ecology 55(5): 1064-1074, illus.

Detling, Leroy E.
1968. Historical background of the flora of the Pacific Northwest. Univ. Oreg. Mus. Nat. Hist. Bull. 13, 57 p., illus.

Duncan, David B.
1955. Multiple range and multiple F tests. Biometrics 11(1):1-42.

Frank, Ernest C., and Richard Lee.
1966. Potential solar beam irradiation on slopes: Tables for 30° to 50° latitude. USDA For. Serv. Res. Pap. RM-18, 116 p., illus. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Hall, Dale O.
1963. The effect of advance growth on ponderosa pine seedling mortality at Challenge Experimental Forest. USDA For. Serv. Res. Note PSW-8, 7 p., illus. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Hallin, William E.
1959. Release of sugar pine seedlings and saplings by harvest cutting. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn. Res. Note 179, 3 p., illus. Portland, Oreg.

Hallin, William E.
1968. Soil moisture tension variation on cutovers in southwestern Oregon. USDA For. Serv. Res. Pap. PNW-58, 18 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Hermann, Richard K., and Harold A. Thomas.
1963. Observations on the occurrence of pocket gophers in southern Oregon pine plantations. J. For. 61(7):527-529, illus.

Mainland, Donald, Lee Herrera, and Marion I. Sutcliffe.
1956. Statistical tables for use with binomial samples: Contingency tests, confidence limits, and sample size estimates. 83 p., N. Y. Univ. Coll. Med., New York.

McDonald, Philip M.
1969. Ponderosa pine seed-tree removal reduces stocking only slightly. J. For. 67(4):226-228, illus.

Minore, Don.
1978. The Dead Indian Plateau: A historical summary of forestry observations and research in a severe southwestern Oregon environment. USDA For. Serv. Gen. Tech. Rep. PNW-72, 23 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Minore, Don, and Richard E. Carkin.
1978. Vegetative indicators, soils, overstory canopy, and natural regeneration after partial cutting on the Dead Indian Plateau of southwestern Oregon. USDA For. Serv. Res. Note PNW-316, 9 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Nolan, Karen S.
1978. Vegetation management and its importance in reforestation: An annotated bibliography. Oreg. State Univ. For. Res. Lab. Res. Note 61, 4 p., Corvallis.

Reynolds, Charles, Nelson Jeffers, Vincent Bousquet, and Roy Stier.
1953. Reforestation surveys. *In* Reports of the Pacific Northwest Seeding and Planting Committee on various recommended reforestation practices and techniques. Chapter 7, p. 61-69, illus. West. For. and Conserv. Assoc., Portland, Oreg.

Stein, William I.
1963. Comparative juvenile growth of five western conifers. Ph. D. thesis. Yale Univ., New Haven, Conn. 194 p., illus.

Stein, William I.
1978. Chapter 11. Reforestation evaluation. *In* Regenerating Oregon's forests, p. 205-221, illus. Brian D. Cleary, Robert D. Greaves, and Richard K. Hermann, compilers and eds. Oreg. State Univ. Ext. Serv., Corvallis.

Williamson, Denis M., and Don Minore.
1978. Survival and growth of planted conifers on the Dead Indian Plateau east of Ashland, Oregon. USDA For. Serv. Res. Pap. PNW-242, 15 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Appendix

Data sources, collection methods, and summation procedures for descriptive and environmental variables.

1. Elevation—height above mean sea level was extrapolated to the nearest 10 feet (3 m) from the plot's location on the applicable U.S. Geological Survey quadrangle map.

2. Average slope—steepness of slope was estimated ocularly to the nearest 10 percent and checked occasionally with a clinometer. Observations for individual subplots were summed and a plot average determined.

3. Aspect index—slope direction was rated to the nearest of eight main compass points. A numerical relative moisture value was then assigned to each subplot from the scale derived by Day and Monk (1974). Values for subplots were summed and a plot average determined.

4. Radiation index—a solar irradiation value was determined for each subplot by entering its slope and aspect in a table of radiation indexes for latitude 42° north calculated by Frank and Lee (1966). Values for subplots were summed and a plot average determined.

5. Average annual precipitation—yearly rainfall was extrapolated to the nearest 2 inches (51 mm) from the plot's approximate location on a small-scale isohyet map of Oregon.

6. Forest type and age class—the general prelogging composition, density, and age of the forest stand were determined from the plot's location on a forest type map. Such maps were prepared in the 1940's as part of the nationwide Forest Survey by the Pacific Northwest Forest and Range Experiment Station, USDA Forest Service.

7. Soil type—soil series were identified from soil inventory maps and descriptions prepared by the Medford District, Bureau of Land Management, in 1973.

8. Years since logging—timber harvest dates were obtained for the cutover area encompassing each plot from cutting reports for individual sales. Years since logging are based on the number of complete growing seasons (ending September 1) between cutting date and examination date. Determined this way, elapsed time data best reflect the actual establishment period available for tree seedlings and fits with the development stage for judging when seedlings are 2 years old or less.

9. Canopy—total vegetative cover present at waist height and above was estimated ocularly to the nearest tenth of the subplot area. Estimates for individual subplots were summed and a plot average determined.

10. Seedbed—the surface condition judged predominant on the subplot immediately after logging was classed as one of five types: bare mineral soil, undisturbed duff and litter; disturbed soil, duff, and litter; mixed soil and rock; or logs, wood, and bark. Duff- and litter-covered subplots and those covered with logs, wood, and bark were counted separately and computed as a percentage of the total subplots on the plot.

11. Seed source—distance to the nearest seed tree was judged as within 50 feet (15.2 m) or over 50 feet in 100-foot (30.5-m) classes. The nearest 16-inch (41-cm) d.b.h. or larger tree with a reasonably full crown was usually considered a source of seed. Trees smaller than 16 inches were recognized if there was evidence they had borne seed in substantial quantities. The species of the nearest seed tree was also recorded. Separately, subplots with a seed tree of any species, of Douglas-fir, or of true fir, within 50 feet were counted and computed as a percentage of the total subplots on the plot.

12. Ground cover—total vegetative cover present below waist height was estimated ocularly to the nearest tenth of the subplot area. Estimates for individual subplots were summed and a plot average determined.

13. Dominant ground cover—vegetative cover was classed as the predominant one of three broad types: grass, herbaceous, or woody perennial. For subplots dominated by woody perennials, the genus or species was recorded if one clearly dominated. Separately, subplots dominated by grass, or woody perennials, were counted and computed as a percentage of the total subplots on the plot.

Table 12—Average stocking in cutovers in the Dead Indian and Butte Falls areas

Descriptor	Dead Indian	Butte Falls	Combined
	PARTIAL CUTS		
Number of samples	44	21	65
Regeneration class (percent ± standard error):[1]			
All	65.1 ± 3.6	81.4 ± 3.4	70.4 ± 2.8
Advance	35.1 ± 3.2	38.8 ± 4.6	36.3 ± 2.6
Subsequent	50.0 ± 3.9	64.5 ± 5.1	54.7 ± 3.2
Second-year[2]	34.9 ± 3.4	26.0 ± 5.4	32.0 ± 2.9
	CLEARCUTS		
Number of samples	16	11	27
Regeneration class (percent ± standard error):[1]			
All	32.8 ± 5.5	74.1 ± 3.6	46.6 ± 5.3
Advance	4.1 ± 1.8	8.6 ± 3.1	5.9 ± 1.7
Subsequent	30.6 ± 5.7	72.3 ± 3.5	47.6 ± 5.4
Second-year[2]	2.2 ± 1.1	3.2 ± 1.2	2.6 ± .8

[1]Data for regeneration classes are not additive since more than 1 class was found on many subplots.

[2]Not included in the "All" and "Subsequent" classes.

Table 13—Proportion of sample plots stocked at 4 levels with regeneration

Stocking at least	Plots	Proportion of total	Confidence limit[1]	
			Lower	Upper
Percent	Number	Proportion		
		44 DEAD INDIAN PARTIAL CUTS		
30	42	0.95	0.85	0.99
50	33	.75	.60	.87
70	24	.55	.39	.70
90	8	.18	.08	.33
		21 BUTTE FALLS PARTIAL CUTS		
30	21	1.00	.84	1.00
50	21	1.00	.84	1.00
70	17	.81	.58	.95
90	9	.43	.22	.66
		16 DEAD INDIAN CLEARCUTS		
30	8	.50	.25	.75
50	4	.25	.07	.52
70	2	.12	.02	.38
90	0	0.	0.	.21
		11 BUTTE FALLS CLEARCUTS		
30	11	1.00	.72	1.00
50	11	1.00	.72	1.00
70	7	.64	.31	.89
90	2	.18	.02	.52

[1]There is a 95-percent or greater chance that the true proportion is within lower and upper confidence limits.

Table 14—Proportion of sample plots stocked at 4 levels with advance regeneration

Stocking at least	Plots	Proportion of total	Confidence limit[1]	
			Lower	Upper
Percent	Number	Proportion		
		44 DEAD INDIAN PARTIAL CUTS		
30	26	0.59	0.43	0.74
50	12	.27	.15	.43
70	5	.11	.04	.24
90	0	0.	0.	.08
		21 BUTTE FALLS PARTIAL CUTS		
30	13	.62	.38	.82
50	8	.38	.18	.62
70	3	.14	.03	.36
90	0	0.	0.	.16
		16 DEAD INDIAN CLEARCUTS		
30	0	0.	0.	.21
50	0	0.	0.	.21
70	0	0.	0.	.21
90	0	0.	0.	.21
		11 BUTTE FALLS CLEARCUTS		
30	1	.09	0.	.41
50	0	0.	0.	.28
70	0	0.	0.	.28
90	0	0.	0.	.28

[1]There is a 95-percent or greater chance that the true proportion is within lower and upper confidence limits.

Table 15—Proportion of sample plots stocked at 4 levels with subsequent regeneration

Stocking at least	Plots	Proportion of total	Confidence limit[1] Lower	Upper
Percent	Number	- - - - - - - - - -Proportion- - - - - - - - - -		
		44 DEAD INDIAN PARTIAL CUTS		
30	35	0.80	0.65	0.90
50	26	.59	.43	.74
70	13	.30	.17	.45
90	4	.09	.03	.22
		21 BUTTE FALLS PARTIAL CUTS		
30	20	.95	.76	1.00
50	18	.86	.64	.97
70	10	.48	.26	.70
90	4	.19	.05	.42
		16 DEAD INDIAN CLEARCUTS		
30	7	.44	.20	.70
50	4	.25	.07	.52
70	2	.12	.02	.38
90	0	0.	0.	.21
		11 BUTTE FALLS CLEARCUTS		
30	11	1.00	.72	1.00
50	11	1.00	.72	1.00
70	7	.64	.31	.89
90	1	.09	0.	.41

[1]There is a 95-percent or greater chance that the true proportion is within lower and upper confidence limits.

Table 16—Proportion of sample plots stocked at 4 levels with subsequent Douglas-fir

Stocking at least	Plots	Proportion of total	Confidence limit[1] Lower	Confidence limit[1] Upper
Percent	Number	Proportion		
		44 DEAD INDIAN PARTIAL CUTS		
30	8	0.18	0.08	0.33
50	4	.09	.03	.22
70	0	0.	0.	.08
90	0	0.	0.	.08
		21 BUTTE FALLS PARTIAL CUTS		
30	12	.57	.34	.78
50	6	.29	.11	.52
70	3	.14	.03	.36
90	0	0.	0.	.16
		16 DEAD INDIAN CLEARCUTS		
30	0	0.	0.	.21
50	0	0.	0.	.21
70	0	0.	0.	.21
90	0	0.	0.	.21
		11 BUTTE FALLS CLEARCUTS		
30	4	.36	.11	.69
50	1	.09	0.	.41
70	0	0.	0.	.28
90	0	0.	0.	.28

[1]There is a 95-percent or greater chance that the true proportion is within lower and upper confidence limits.

Table 17—Proportion of sample plots stocked at 4 levels with subsequent true firs

Stocking at least	Plots	Proportion of total	Confidence limit[1]	
			Lower	Upper
Percent	Number	Proportion		
		44 DEAD INDIAN PARTIAL CUTS		
30	28	0.64	0.48	0.78
50	17	.39	.25	.55
70	4	.09	.03	.22
90	1	.02	0.	.12
		21 BUTTE FALLS PARTIAL CUTS		
30	14	.67	.43	.85
50	6	.29	.11	.52
70	1	.05	0.	.24
90	0	0.	0.	.16
		16 DEAD INDIAN CLEARCUTS		
30	1	.06	0.	.30
50	1	.06	0.	.30
70	0	0.	0.	.21
90	0	0.	0.	.21
		11 BUTTE FALLS CLEARCUTS		
30	1	.09	0.	.41
50	1	.09	0.	.41
70	0	0.	0.	.28
90	0	0.	0.	.28

[1]There is a 95-percent or greater chance that the true proportion is within lower and upper confidence limits.

Table 18—Average stocking by species in cutovers in the Dead Indian and Butte Falls areas

Descriptor	Dead Indian		Butte Falls	
	Partial cut	Clearcut	Partial cut	Clearcut
Number of samples	44	16	21	11
Species (percent ± standard error):[1]				
Douglas-fir	18.8 ± 2.5	3.8 ± 1.6	49.3 ± 4.5	20.0 ± 5.6
True firs	54.2 ± 3.4	11.6 ± 3.3	56.0 ± 4.7	14.1 ± 5.2
Ponderosa pine	1.6 ± .7	18.1 ± 5.1	1.9 ± 1.1	58.6 ± 6.2
Sugar and western white pine	4.3 ± 1.3	1.3 ± .7	2.4 ± .8	1.8 ± 1.0
Incense-cedar	12.5 ± 3.9	2.8 ± 1.2	45.2 ± 6.0	6.4 ± 1.7
Other conifers	.9 ± .6	2.8 ± 1.6	5.7 ± 2.6	1.4 ± 1.4
Hardwoods	3.1 ± .8	.9 ± .9	7.9 ± 2.7	1.4 ± 1.4
All species	65.1 ± 3.6	32.8 ± 5.5	81.4 ± 3.4	74.1 ± 3.6

[1]Does not include second-year seedlings.

Table 19—Average stocking of advance and subsequent regeneration by species in cutovers in the Dead Indian and Butte Falls areas

Descriptor	Dead Indian		Butte Falls	
	Advance	Subsequent	Advance	Subsequent
		PARTIAL CUTS		
Number of samples	44	44	21	21
Species (percent ± standard error):[1]				
Douglas-fir	4.0 ± 0.9	15.5 ± 2.5	17.1 ± 3.6	38.1 ± 4.8
True firs	29.3 ± 3.0	37.8 ± 3.4	25.2 ± 4.1	38.1 ± 4.4
Ponderosa pine	.2 ± .2	1.5 ± .7	1.0 ± .7	1.0 ± .4
Sugar and western white pine	1.5 ± .6	3.1 ± 1.2	.7 ± .4	1.7 ± .8
Incense-cedar	2.3 ± 1.2	11.8 ± 3.8	9.3 ± 2.4	39.5 ± 5.9
Other conifers	.1 ± .1	.8 ± .6	3.1 ± 1.3	3.1 ± 1.5
Hardwoods	2.6 ± .7	1.2 ± .6	3.3 ± 1.4	4.8 ± 2.2
All species	35.1 ± 3.2	50.0 ± 3.9	38.8 ± 4.6	64.5 ± 5.1
		CLEARCUTS		
Number of samples	16	16	11	11
Species (percent ± standard error):[1]				
Douglas-fir	.9 ± .7	2.8 ± 1.5	5.0 ± 1.8	17.7 ± 6.0
True firs	3.1 ± 1.6	9.4 ± 3.1	5.9 ± 2.1	10.5 ± 4.3
Ponderosa pine	0.	18.1 ± 5.1	0.	58.6 ± 6.2
Sugar and western white pine	.6 ± .6	.6 ± .4	0.	1.8 ± 1.0
Incense-cedar	.6 ± .6	2.5 ± 1.0	.9 ± .9	6.4 ± 1.7
Other conifers	0.	2.8 ± 1.6	.5 ± .5	.9 ± .9
Hardwoods	0.	.9 ± .9	.5 ± .5	.9 ± .9
All species	4.1 ± 1.8	30.6 ± 5.7	8.6 ± 3.1	72.3 ± 3.5

[1]Does not include second-year seedlings.

Table 20—Average stocking of second-year seedlings by species in cutovers in the Dead Indian and Butte Falls areas

Descriptor	Dead Indian		Butte Falls	
	Partial cut	Clearcut	Partial cut	Clearcut
Number of samples	44	16	21	11
Species (percent ± standard error):				
Douglas-fir	4.5 ± 1.1	0.3 ± 0.3	3.3 ± 0.9	1.4 ± 0.7
True firs	29.5 ± 3.2	1.9 ± .9	8.8 ± 1.9	1.8 ± 1.0
Ponderosa pine	.1 ± .1	0.	.7 ± .5	0.
Sugar and western white pine	.3 ± .3	0.	0.	0.
Incense-cedar	5.3 ± 2.4	.3 ± .3	18.3 ± 5.1	0.
Other conifers	0.	0.	1.0 ± .6	0.
Hardwoods	.1 ± .1	0.	0.	0.
All species	34.9 ± 3.4	2.2 ± 1.1	26.0 ± 5.4	3.2 ± 1.2

Table 21—Significant associations between total or advance stocking in partial cuts and environmental variables by area

Stocking category	Environmental variable and its correlation coefficient (r)[1, 2]					
	Dead Indian		Butte Falls		Areas combined	
Total	Radiation index	-0.33*	Ground cover	-0.54*	Elevation	-0.26*
	Woody perennials	.35*	Grass	-.59**	Radiation index	-.29*
	True fir seed source	-.40**	Duff & litter	-.39	Woody perennials	.29*
			Undisturbed seedbed	-.48*	Douglas-fir seed source	.22
					True fir seed source	-.42**
Advance all species	Woody perennials	.31*	Elevation	-.37	Canopy	.22
	Undisturbed seedbed	.26	Canopy	.68**	Ground cover	-.27*
			Ground cover	-.38	Woody perennials	.26*
			Duff & litter	.53*	Duff & litter	.28*
			Precipitation	-.48*	Undisturbed seedbed	.33**
			Undisturbed seedbed	.45*		
Advance Douglas-fir	Radiation index	-.30*	Elevation	-.40	Elevation	-.59**
	Aspect	.35*	Canopy	.52*	Canopy	.24
			Ground cover	-.40	Duff & litter	.40**
			Duff & litter	.45*	Douglas-fir seed source	.38**
			True fir seed source	-.39	True fir seed source	-.44**
			Precipitation	-.56**	Undisturbed seedbed	.28*
Advance true firs	Ground cover	-.30*	Aspect	-.44*	Canopy	.22
	Woody perennials	.32*	Canopy	.67**	Ground cover	-.35**
	Undisturbed seedbed	.37*	Ground cover	-.52*	Woody perennials	.27*
			Duff & litter	.49*	Duff & litter	.25*
			Precipitation	-.42	Undisturbed seedbed	.35**
			Undisturbed seedbed	.47*		
Advance incense-cedar	Grass	.37*			Elevation	-.32**
	Undisturbed seedbed	-.26			True fir seed source	-.36**
					Precipitation	.23

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 42, 19, and 63 for Dead Indian, Butte Falls, and combined data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 22—Significant associations between subsequent stocking in partial cuts and environmental variables by area

Stocking category	Dead Indian		Butte Falls		Areas combined	
	Environmental variable and its correlation coefficient (r)[1, 2]					
Total subsequent	Elevation	-0.29	Canopy	-0.40	Elevation	-0.24
	Radiation index	-.40**	Duff & litter	-.59**	Radiation index	-.34**
	Aspect	.29	Undisturbed seedbed	-.69**	Aspect	.23
	Woody perennials	.31*			Canopy	-.21
	True fir seed source	-.52**			Douglas-fir seed source	.27*
					True fir seed source	-.43**
Second-year	Elevation	.33*	Douglas-fir seed source	-.39	Elevation	.25*
	Woody perennials	-.32*			Grass	-.21
	Precipitation	.40**			Woody perennials	-.35**
					Douglas-fir seed source	-.27*
Douglas-fir	Elevation	-.34*	Canopy	-.41	Elevation	-.47**
	Duff & litter	-.27	Duff & litter	-.47*	Radiation index	-.31*
	Douglas-fir seed source	.69**	Undisturbed seedbed	-.47*	Woody perennials	.25*
	True fir seed source	-.40**			Douglas-fir seed source	.68**
	Precipitation	-.49**			True fir seed source	-.49**
					Precipitation	.23
True firs	Radiation index	-.53**	Radiation index	-.46*	Radiation index	-.47**
	Aspect	.38*	Aspect	.44*	Aspect	.39**
	Years	.25	Precipitation	.47*	Years	.25*
	Ground cover	.29				
	Woody perennials	.30*				
	Precipitation	-.37*				
Incense-cedar	Ground cover	-.31*	Elevation	.41	Elevation	-.31*
	True fir seed source	-.43**	Years	.42	Ground cover	-.28*
			Woody perennials	-.42	True fir seed source	-.45**
			Duff & litter	-.45*	Precipitation	.37**
			Undisturbed seedbed	-.55**		

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 42, 19, and 63 for Dead Indian, Butte Falls, and combined data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 23—Significant associations between total or advance stocking in clearcuts and environmental variables by area

Stocking category	Environmental variable and its correlation coefficient (r)[1, 2]					
	Dead Indian		Butte Falls		Areas combined	
Total	Radiation index	-0.43	Elevation	-0.76**	Elevation	-0.72**
	Woody perennials	.58*	Slope	-.54	Grass	-.42*
			Seed source distance	.85**	Woody perennials	.68**
					Duff & litter	.47*
					Precipitation	.53**
					Undisturbed seedbed	.40*
Advance all species	Ground cover	-.47	Duff & litter	.90**	Duff & litter	.66**
			Logs, wood, bark	.58	Logs, wood, bark	.43*
			Seed source distance	.55	Undisturbed seedbed	.67**
			Undisturbed seedbed	.87**		
Advance Douglas-fir	Ground cover	-.65**	Duff & litter	.78**	Elevation	-.43*
			Undisturbed seedbed	.72*	Duff & litter	.72**
					Logs, wood, bark	.35
					Precipitation	.42*
					Undisturbed seedbed	.66**
Advance true firs	Ground cover	-.57*	Years	-.53	Ground cover	-.44*
	Seed source distance	.44	Duff & litter	.89**	Duff & litter	.56**
			Undisturbed seedbed	.80**	Logs, wood, bark	.40*
					Seed source distance	.35
					Undisturbed seedbed	.60**
Advance incense-cedar			Years	-.70*		

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 14, 9, and 25 for Dead Indian, Butte Falls, and combined data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 24—Significant associations between subsequent stocking in clearcuts and environmental variables by area

Stocking category	Environmental variable and its correlation coefficient (r)[1, 2]					
	Dead Indian		Butte Falls		Areas combined	
Total subsequent	Radiation index	-0.47	Elevation	-0.80**	Elevation	-0.72**
	Woody perennials	.57*	Slope	-.67*	Grass	-.42*
			Seed source distance	.73*	Woody perennials	.67**
			Precipitation	-.61*	Duff & litter	.42*
					Precipitation	.52**
					Undisturbed seedbed	.33
Second-year	Woody perennials	.46	Ground cover	-.57	Radiation index	.37
			Precipitation	.55	Aspect	-.38*
					Woody perennials	.34
Douglas-fir	Grass	-.48	Elevation	.71*	Slope	.53**
	Woody perennials	.68**	Aspect	.53	Grass	-.50**
	Duff & litter	.46	Slope	.56	Woody perennials	.66**
			Grass	-.55	Duff & litter	.36
			Woody perennials	.64*	Precipitation	.76**
			Precipitation	.87**		
True firs	Radiation index	-.62**	Duff & litter	.76**	Radiation index	-.47*
	Woody perennials	.55*	Logs, wood, bark	.65*	Grass	-.33
	Duff & litter	.49	Seed source distance	.58	Woody perennials	.38*
	Undisturbed seedbed	.52*	Undisturbed seedbed	.83**	Duff & litter	.53**
					Logs, wood, bark	.53**
					Undisturbed seedbed	.66**
Incense-cedar	Ground cover	.48	Radiation index	.64*	Elevation	-.34
					Ground cover	.33
					Woody perennials	.40*

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 14, 9, and 25 for Dead Indian, Butte Falls, and combined data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 25—Significant associations between total or advance stocking in partial cuts and environmental variables by forest type

Stocking category	Environmental variable and its correlation coefficient (r)[1, 2]					
	Douglas-fir		White fir		Pine	
Total	Logs, wood, bark	-0.47*	True fir seed source	-0.39*	Radiation index	-0.62*
	True fir seed source	-.42			Aspect	.53
	Precipitation	.48*				
Advance all species	Elevation	-.52*			Aspect	.49
	Aspect	-.37			Duff & litter	.51
	Canopy	.57**			Undisturbed seedbed	.48
	Ground cover	-.45*				
	Grass	-.45*				
	Duff & litter	.64**				
	Undisturbed seedbed	.56**				
Advance Douglas-fir	Elevation	-.52*	Elevation	-.62**	Radiation index	-.55*
	Aspect	-.39	Douglas-fir seed source	.55**		
	Canopy	.48*	True fir seed source	-.47**		
	Ground cover	-.56**				
	Duff & litter	.62**				
	Undisturbed seedbed	.39				
Advance true firs	Elevation	-.40	Elevation	.31	Radiation index	-.48
	Aspect	-.46*	Aspect	-.39*	Woody perennials	.55*
	Canopy	.65**			Duff & litter	.63*
	Ground cover	-.46*			Undisturbed seedbed	.77**
	Duff & litter	.70**				
	Undisturbed seedbed	.62**				
Advance incense-cedar	Ground cover	-.41	Elevation	-.48**		
	Grass	-.38	True fir seed source	-.41*		
	True fir seed source	-.41				
	Precipitation	.40				

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 19, 27, and 11 for Douglas-fir, white fir, and pine type data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 26—Significant associations between subsequent stocking in partial cuts and environmental variables by forest type

Stocking category	Environmental variable and its correlation coefficient (r)[1, 2]					
	Douglas-fir		White fir		Pine	
Total subsequent	Years	0.41	Elevation	-0.36	Radiation index	-0.53
	Logs, wood, bark	-.39	Douglas-fir seed source	.35		
	Undisturbed seedbed	-.59**	True fir seed source	-.47**		
Second-year	Elevation	.38	Grass	-.47**	Elevation	-.49
	Aspect	.38			Woody perennials	-.64*
					Duff & litter	-.48
					Precipitation	.63*
Douglas-fir	Duff & litter	-.37	Elevation	-.63**	Elevation	-.64*
	Douglas-fir seed source	.38	Woody perennials	.42*	Radiation index	-.51
	Undisturbed seedbed	-.52*	Douglas-fir seed source	.65**	Slope	.80**
			True fir seed source	-.63**	Years	-.52
					Grass	-.53
True firs	Radiation index	-.45*	Radiation index	-.38*		
	Aspect	.54*				
Incense-cedar	Ground cover	-.43*	Elevation	-.32	Elevation	-.70**
	Grass	-.47*	True fir seed source	-.53**	Radiation index	-.54
	Precipitation	.56**			True fir seed source	-.53

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 19, 27, and 11 for Douglas-fir, white fir, and pine type data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 27—Significant associations between total or advance stocking in clearcuts and environmental variables by forest type

Stocking category	Environmental variable and its correlation coefficient (r)[1, 2]			
	Douglas-fir		White fir	
Total	Elevation	-0.88**	Elevation	-0.75**
	Slope	.63*	Ground cover	-.52
	Grass	-.80**	Precipitation	.52
	Woody perennials	.91**	Undisturbed seedbed	.47
	Duff & litter	.58*		
	Precipitation	.77**		
Advance all species	Duff & litter	.61*	Radiation index	.50
	Logs, wood, bark	.81**	Duff & litter	.72**
	Seed source distance	.53	Undisturbed seedbed	.49
	Undisturbed seedbed	.80**		
Advance Douglas-fir	Elevation	-.59*	Radiation index	.47
	Woody perennials	.52	Ground cover	-.47
	Duff & litter	.60*	Duff & litter	.86**
	Logs, wood, bark	.60*	Precipitation	.59*
	Undisturbed seedbed	.67*	Undisturbed seedbed	.66**
Advance true firs	Logs, wood, bark	.75**	Radiation index	.51
	Seed source distance	.58*	Duff & litter	.88**
	Undisturbed seedbed	.60*	Precipitation	.54*
			Undisturbed seedbed	.61*
Advance incense-cedar	Years	-.53		

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 11 and 12 for Douglas-fir and white fir type data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 28—Significant associations between subsequent stocking in clearcuts and environmental variables by forest type

Stocking category	Environmental variable and its correlation coefficient (r)[1, 2]			
	Douglas-fir		White fir	
Total subsequent	Elevation	-0.88**	Elevation	-0.75**
	Slope	.63*	Ground cover	-.50
	Ground cover	.50	Precipitation	.51
	Grass	-.80**		
	Woody perennials	.90**		
	Duff & litter	.52		
	Precipitation	.77**		
Second-year				
Douglas-fir	Elevation	-.58*	Woody perennials	.60*
	Slope	.63*		
	Grass	-.63*		
	Woody perennials	.80**		
	Precipitation	.89**		
True firs	Duff & litter	.74**	Radiation index	-.50
	Logs, wood, bark	.75**	Undisturbed seedbed	.47
	Undisturbed seedbed	.83**		
Incense-cedar	Elevation	-.68**	Duff & litter	.49
	Ground cover	.56*	Undisturbed seedbed	.52
	Woody perennials	.49		

[1]Degrees of freedom for the significant correlations in each stocking category are respectively 11 and 12 for Douglas-fir and white fir type data sets.

[2]Correlation coefficients with 0, 1, or 2 asterisks are significant at the 10-, 5-, and 1-percent probability levels, respectively. To determine the amount of total variation accounted for by any single independent variable, square its r value.

Table 29—Regressions between stocking and environmental variables for Dead Indian partial cuts

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	221.48	-0.31	(true fir seed source)	0.16	2/41	6.81**
		-289.49	(radiation index)	.25		
Advance all species	30.78	+0.25	(woody perennials)	.10	2/41	4.06*
		-0.27	(Douglas-fir seed source)	.17		
Advance Douglas-fir	-0.38	+0.49	(aspect)	.12	1/42	5.70*
Advance true firs	15.53	+0.30	(undisturbed seedbed)	.14	3/40	4.37**
		+0.19	(woody perennials)	.19		
		-0.23	(Douglas-fir seed source)	.25		
Advance incense-cedar	-0.98	+0.20	(grass)	.14	1/42	6.60*
Total subsequent	252.51	-0.45	(true fir seed source)	.27	2/41	13.89***
		-369.49	(radiation index)	.40		
Second-year	-21.10	+1.63	(precipitation)	.16	6/37	4.49**
		-0.24	(woody perennials)	.25		
		-0.30	(grass)	.29		
		+1.76	(aspect)	.34		
		+0.42	(canopy)	.38		
		-0.18	(true fir seed source)	.42		
Subsequent Douglas-fir	7.27	+0.56	(Douglas-fir seed source)	.47	2/41	21.40***
		-0.44	(slope)	.51		
Subsequent true firs	264.95	-426.41	(radiation index)	.28	3/40	9.83***
		-1.19	(precipitation)	.38		
		+1.32	(years)	.42		
Subsequent incense-cedar	88.69	-0.77	(true fir seed source)	.19	3/40	10.52***
		-0.79	(Douglas-fir seed source)	.40		
		-1.48	(years)	.44		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

Table 30—Regressions between stocking and environmental variables for Butte Falls partial cuts

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	90.14	-0.70	(grass)	0.35	3/17	10.78***
		-0.28	(woody perennials)	.55		
		+1.94	(years)	.66		
Advance all species	72.29	+0.78	(canopy)	.46	3/17	10.37***
		-0.012	(elevation)	.54		
		-0.54	(ground cover)	.65		
Advance Douglas-fir	67.85	-1.31	(precipitation)	.32	4/16	6.01**
		-0.46	(grass)	.46		
		+0.23	(undisturbed seedbed)	.53		
		-0.23	(true fir seed source)	.60		
Advance true firs	19.02	+0.73	(canopy)	.45	2/18	13.81***
		-0.56	(ground cover)	.61		
Advance incense-cedar	21.16	-0.77	(true fir seed source)	.09	6/14	6.35**
		0.47	(Douglas-fir seed source)	.41		
		-0.42	(grass)	.52		
		+0.25	(canopy)	.59		
		+1.59	(years)	.66		
		+0.31	(ground cover)	.73		
Total subsequent	69.51	-0.60	(undisturbed seedbed)	.47	5/15	11.97***
		+0.90	(true fir seed source)	.52		
		+0.70	(Douglas-fir seed source)	.57		
		-0.60	(woody perennials)	.70		
		-0.47	(grass)	.80		
Second-year	155.79	-0.57	(Douglas-fir seed source)	.16	4/16	3.00*
		-0.34	(undisturbed seedbed)	.25		
		-0.020	(elevation)	.32		
		-0.54	(grass)	.43		
Subsequent Douglas-fir	-24.05	-0.49	(undisturbed seedbed)	.22	4/16	5.90**
		+0.65	(Douglas-fir seed source)	.35		
		+0.55	(true fir seed source)	.52		
		+0.86	(precipitation)	.60		
Subsequent true firs	184.18	+2.51	(precipitation)	.22	7/13	7.73***
		+5.23	(years)	.33		
		-520.48	(radiation index)	.46		
		+0.93	(canopy)	.62		
		-0.35	(woody perennials)	.68		
		-3.34	(aspect)	.75		
		-0.011	(elevation)	.81		
Subsequent incense-cedar	84.88	-0.63	(undisturbed seedbed)	.30	5/15	6.39**
		+0.019	(elevation)	.44		
		-1.41	(precipitation)	.55		
		-0.39	(woody perennials)	.60		
		-0.54	(grass)	.68		

[1] 1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

Table 31—Regressions between stocking and environmental variables for combined data from Dead Indian and Butte Falls partial cuts

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	169.99	-0.28	(true fir seed source)	0.18	2/62	10.09***
		-182.78	(radiation index)	.25		
Advance all species	36.47	+0.31	(undisturbed seedbed)	.11	2/62	5.50**
		-0.27	(ground cover)	.15		
Advance Douglas-fir	57.00	-0.009	(elevation)	.34	2/62	19.27***
		-0.15	(ground cover)	.38		
Advance true firs	46.55	+0.29	(undisturbed seedbed)	.13	5/59	6.13***
		-0.32	(ground cover)	.21		
		-0.49	(precipitation)	.26		
		-0.17	(Douglas-fir seed source)	.29		
		+0.17	(woody perennials)	.34		
Advance incense-cedar	39.25	-0.17	(true fir seed source)	.13	3/61	6.85***
		-0.19	(Douglas-fir seed source)	.20		
		-0.004	(elevation)	.25		
Total subsequent	177.92	-0.31	(true fir seed source)	.18	3/61	9.32***
		-251.65	(radiation index)	.28		
		+1.42	(years)	.31		
Second-year	55.16	-0.26	(woody perennials)	.12	3/61	6.01**
		-0.42	(grass)	.19		
		-0.16	(Douglas-fir seed source)	.23		
Subsequent Douglas-fir	96.60	+0.50	(Douglas-fir seed source)	.46	3/61	27.87***
		-175.91	(radiation index)	.54		
		-0.21	(undisturbed seedbed)	.58		
Subsequent true firs	176.59	-321.81	(radiation index)	.22	2/62	12.82***
		+1.70	(years)	.29		
Subsequent incense-cedar	30.60	-0.63	(true fir seed source)	.20	3/61	11.34***
		+1.06	(precipitation)	.29		
		-0.40	(Douglas-fir seed source)	.36		

[1]2 asterisks denote significance of the regression F ratio at the 1-percent probability level; 3, 0.1-percent.

Table 32—Regressions between stocking and environmental variables for Dead Indian clearcuts

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	291.98	+0.65	(woody perennials)	0.34	4/11	6.51**
		+5.45	(precipitation)	.43		
		-453.30	(radiation index)	.58		
		-0.039	(elevation)	.70		
Advance all species	20.98	-0.28	(ground cover)	.22	1/14	[2]3.88
Advance Douglas-fir	9.89	-0.15	(ground cover)	.42	1/14	10.00**
Advance true firs	31.32	-0.31	(ground cover)	.32	3/12	4.07*
		+0.09	(seed source distance)	.41		
		-0.96	(years)	.50		
Advance incense-cedar	-28.66	+0.005	(elevation)	.06	3/12	[3]1.72
		-0.49	(precipitation)	.22		
		+36.87	(radiation index)	.30		
Total subsequent	322.85	+0.65	(woody perennials)	.33	4/11	7.40**
		+5.73	(precipitation)	.41		
		-530.92	(radiation index)	.61		
		-0.040	(elevation)	.73		
Second-year	-62.12	+0.10	(woody perennials)	.21	4/11	6.11**
		+126.86	(radiation index)	.53		
		+0.07	(seed source distance)	.58		
		+0.22	(slope)	.69		
Subsequent Douglas-fir	50.18	+0.19	(woody perennials)	.47	4/11	13.21***
		-0.021	(elevation)	.60		
		+0.62	(slope)	.76		
		+102.32	(radiation index)	.83		
Subsequent true firs	375.07	-752.43	(radiation index)	.39	3/12	9.84**
		-3.12	(aspect)	.64		
		+0.64	(undisturbed seedbed)	.71		
Subsequent incense-cedar	16.26	+0.06	(ground cover)	.23	4/11	4.20*
		-0.71	(precipitation)	.36		
		-0.44	(undisturbed seedbed)	.49		
		+0.06	(woody perennials)	.60		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant at the 10-percent level.

[3]Significant between the 10- and 25-percent level.

Table 33—Regressions between stocking and environmental variables for Butte Falls clearcuts

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	84.69	+0.49	(seed source distance)	0.72	2/8	33.19***
		-0.54	(precipitation)	.89		
Advance all species	-41.62	+0.73	(undisturbed seedbed)	.76	2/8	18.08**
		+89.66	(radiation index)	.82		
Advance Douglas-fir	-164.89	+0.54	(undisturbed seedbed)	.52	4/6	6.83*
		+283.36	(radiation index)	.65		
		+1.79	(aspect)	.71		
		+1.30	(years)	.82		
Advance true firs	-151.37	+0.55	(undisturbed seedbed)	.65	4/6	23.12***
		+317.55	(radiation index)	.73		
		+2.54	(aspect)	.89		
		-0.30	(ground cover)	.94		
Advance incense-cedar	22.87	-1.57	(years)	.49	2/8	10.37**
		-0.13	(undisturbed seedbed)	.72		
Total subsequent	101.19	-0.012	(elevation)	.65	4/6	28.03***
		+1.50	(aspect)	.84		
		+0.21	(seed source distance)	.89		
		-0.41	(slope)	.95		
Second-year	6.36	-0.09	(ground cover)	.33	5/5	37.26***
		+0.75	(precipitation)	.59		
		-0.16	(seed source distance)	.77		
		-0.013	(elevation)	.91		
		+43.48	(radiation index)	.97		
Subsequent Douglas-fir	-64.11	+1.68	(precipitation)	.75	2/8	19.97***
		+1.97	(aspect)	.83		
Subsequent true firs	-88.97	+0.89	(undisturbed seedbed)	.68	4/6	21.90***
		+0.027	(elevation)	.78		
		+0.35	(seed source distance)	.89		
		-0.47	(slope)	.94		
Subsequent incense-cedar	-116.39	+195.85	(radiation index)	.41	3/7	6.18*
		+0.42	(ground cover)	.57		
		+0.12	(woody perennials)	.73		

[1] 1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

Table 34—Regressions between stocking and environmental variables for combined data from Dead Indian and Butte Falls clearcuts

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	108.33	-0.017	(elevation)	0.52	2/24	26.90***
		+0.42	(woody perennials)	.69		
Advance all species	-52.92	+0.65	(undisturbed seedbed)	.45	2/24	14.92***
		+116.78	(radiation index)	.55		
Advance Douglas-fir	-35.42	+0.33	(undisturbed seedbed)	.44	3/23	14.34***
		+69.75	(radiation index)	.59		
		+0.12	(precipitation)	.65		
Advance true firs	17.56	+0.39	(undisturbed seedbed)	.36	2/24	12.87***
		-0.27	(ground cover)	.52		
Advance incense-cedar	-45.73	-0.33	(years)	.10	3/23	3.68*
		+98.50	(radiation index)	.13		
		+0.64	(aspect)	.32		
Total subsequent	108.21	-0.018	(elevation)	.52	2/24	25.29***
		+0.41	(woody perennials)	.68		
Second-year	3.94	-0.57	(aspect)	.15	4/22	5.95**
		+0.10	(woody perennials)	.35		
		+0.002	(elevation)	.44		
		-0.14	(ground cover)	.52		
Subsequent Douglas-fir	15.85	+1.18	(precipitation)	.58	5/21	16.30***
		-146.66	(radiation index)	.70		
		+0.16	(woody perennials)	.74		
		+0.13	(seed source distance)	.76		
		+0.004	(elevation)	.80		
Subsequent true firs	82.97	+0.66	(undisturbed seedbed)	.43	4/22	11.24***
		-171.16	(radiation index)	.56		
		+0.18	(seed source distance)	.60		
		-0.12	(grass)	.67		
Subsequent incense-cedar	-113.17	+0.06	(woody perennials)	.16	4/22	6.28**
		+209.97	(radiation index)	.29		
		+0.93	(aspect)	.43		
		+0.18	(ground cover)	.53		

[1] 1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

Table 35—Regressions between stocking and environmental variables for partial cuts in the Douglas-fir type

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	-2.17	+1.26	(precipitation)	0.23	4/16	7.05**
		+3.76	(years)	.44		
		+0.59	(canopy)	.52		
		-0.36	(undisturbed seedbed)	.64		
Advance all species	25.39	+0.94	(canopy)	.32	3/17	10.54***
		-0.012	(elevation)	.54		
		+0.76	(slope)	.65		
Advance Douglas-fir	34.51	-0.33	(ground cover)	.31	4/16	9.57***
		-0.009	(elevation)	.45		
		+2.33	(years)	.60		
		+0.32	(canopy)	.71		
Advance true firs	-34.57	+0.83	(canopy)	.42	4/16	11.08***
		+0.35	(undisturbed seedbed)	.59		
		-0.20	(true fir seed source)	.68		
		+0.18	(woody perennials)	.73		
Advance incense-cedar	0.10	-0.43	(true fir seed source)	.17	4/16	6.54**
		-0.43	(Douglas-fir seed source)	.51		
		+0.32	(precipitation)	.55		
		+73.45	(radiation index)	.62		
Total subsequent	19.07	-0.68	(undisturbed seedbed)	.35	4/16	10.00***
		+1.52	(precipitation)	.47		
		+5.19	(years)	.63		
		-1.06	(slope)	.71		
Second-year	75.80	+0.019	(elevation)	.14	5/15	3.73*
		-275.82	(radiation index)	.24		
		-0.43	(true fir seed source)	.34		
		-0.25	(woody perennials)	.45		
		+0.55	(canopy)	.55		
Subsequent Douglas-fir	80.07	-0.47	(undisturbed seedbed)	.27	5/15	5.66**
		+1.53	(precipitation)	.46		
		-1.37	(slope)	.52		
		+3.09	(years)	.59		
		-163.94	(radiation index)	.65		
Subsequent true firs	-28.99	+4.27	(aspect)	.29	5/15	4.37*
		-0.27	(woody perennials)	.41		
		+0.61	(canopy)	.47		
		+1.00	(precipitation)	.54		
		-0.85	(slope)	.59		
Subsequent incense-cedar	-48.94	+1.89	(precipitation)	.31	4/16	12.14***
		+7.19	(years)	.53		
		-2.61	(aspect)	.68		
		-0.29	(woody perennials)	.75		

[1] 1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

Table 36—Regressions between stocking and environmental variables for partial cuts in the white fir type

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	111.48	-0.44	(true fir seed source)	0.15	3/25	4.38*
		-0.53	(grass)	.27		
		-0.32	(undisturbed seedbed)	.34		
Advance all species	31.80	+0.21	(Douglas-fir seed source)	.09	1/27	[2]2.77
Advance Douglas-fir	59.64	-0.011	(elevation)	.38	2/26	9.84***
		-0.18	(grass)	.43		
Advance true firs	153.78	-2.64	(aspect)	.15	3/25	4.51*
		+0.007	(elevation)	.25		
		-282.23	(radiation index)	.35		
Advance incense-cedar	38.83	-0.007	(elevation)	.23	2/26	5.18*
		-0.12	(Douglas-fir seed source)	.29		
Total subsequent	121.34	-0.52	(true fir seed source)	.22	3/25	6.87**
		-0.67	(grass)	.31		
		-0.71	(canopy)	.45		
Second-year	30.91	-0.71	(grass)	.22	2/26	6.28**
		+2.34	(years)	.33		
Subsequent Douglas-fir	36.94	+0.15	(Douglas-fir seed source)	.42	5/23	8.94***
		-0.28	(grass)	.50		
		-0.007	(elevation)	.57		
		+0.12	(woody perennials)	.61		
		+0.95	(years)	.66		
Subsequent true firs	139.25	-265.05	(radiation index)	.15	3/25	3.67*
		+1.84	(years)	.22		
		+0.20	(woody perennials)	.31		
Subsequent incense-cedar	60.24	-0.70	(true fir seed source)	.28	4/24	10.70***
		-0.65	(grass)	.43		
		-0.56	(undisturbed seedbed)	.56		
		+1.02	(precipitation)	.64		

[1] 1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2] Significant near the 10-percent level.

Table 37—Regressions between stocking and environmental variables for partial cuts in the pine type

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	444.97	-840.42	(radiation index)	0.38	4/8	6.04*
		+0.52	(woody perennials)	.51		
		+0.58	(grass)	.63		
		-0.35	(true fir seed source)	.75		
Advance all species	11.87	+4.15	(aspect)	.24	4/8	7.22**
		+0.82	(undisturbed seedbed)	.54		
		-0.42	(true fir seed source)	.69		
		-1.23	(slope)	.78		
Advance Douglas-fir	73.84	-156.26	(radiation index)	.30	4/8	[2]3.68
		-0.26	(Douglas-fir seed source)	.47		
		+0.16	(undisturbed seedbed)	.56		
		-0.08	(true fir seed source)	.65		
Advance true firs	-30.42	+1.04	(undisturbed seedbed)	.59	2/10	24.54***
		+3.13	(aspect)	.83		
Advance incense-cedar	123.90	+0.41	(grass)	.20	4/8	[2]3.04
		-0.38	(undisturbed seedbed)	.41		
		-271.86	(radiation index)	.52		
		+0.23	(ground cover)	.60		
Total subsequent	369.64	-618.88	(radiation index)	.28	4/8	4.77*
		-0.51	(true fir seed source)	.43		
		-0.89	(Douglas-fir seed source)	.59		
		+0.34	(woody perennials)	.70		
Second-year	64.57	-0.96	(woody perennials)	.40	4/8	6.81*
		-2.59	(years)	.63		
		+1.61	(slope)	.68		
		+0.64	(undisturbed seedbed)	.77		
Subsequent Douglas-fir	-19.69	+1.21	(slope)	.64	3/9	28.88***
		+1.08	(aspect)	.81		
		+0.11	(true fir seed source)	.91		
Subsequent true firs	-24.19	+0.42	(woody perennials)	.20	4/8	[2]2.82
		-0.43	(Douglas-fir seed source)	.36		
		+2.88	(aspect)	.45		
		+0.51	(ground cover)	.59		
Subsequent incense-cedar	528.30	-0.093	(elevation)	.49	3/9	10.58**
		-0.68	(true fir seed source)	.67		
		-2.09	(slope)	.78		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant at the 10-percent level.

Table 38—Regressions between stocking and environmental variables for clearcuts in the Douglas-fir type

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
Total	18.41	+0.72	(woody perennials)	0.84	1/11	56.05***
Advance all species	-4.79	+0.39	(undisturbed seedbed)	.64	3/9	10.29**
		+0.19	(seed source distance)	.69		
		+0.11	(woody perennials)	.77		
Advance Douglas-fir	23.15	+0.11	(undisturbed seedbed)	.45	3/9	6.60*
		-0.005	(elevation)	.58		
		+0.09	(seed source distance)	.69		
Advance true firs	-0.52	+0.30	(undisturbed seedbed)	.36	2/10	4.80*
		+0.12	(seed source distance)	.49		
Advance incense-cedar	12.44	-0.84	(years)	.28	2/10	[2]3.38
		-0.04	(seed source distance)	.40		
Total subsequent	-24.18	+0.64	(woody perennials)	.80	2/10	35.22***
		+0.73	(ground cover)	.88		
Second-year	10.39	+0.21	(precipitation)	.20	2/10	5.94*
		-0.25	(ground cover)	.54		
Subsequent Douglas-fir	133.43	+1.84	(precipitation)	.79	3/9	34.81***
		-362.91	(radiation index)	.86		
		-0.83	(slope)	.92		
Subsequent true firs	78.46	+0.94	(undisturbed seedbed)	.70	2/10	18.64***
		-168.23	(radiation index)	.79		
Subsequent incense-cedar	62.33	-0.011	(elevation)	.46	3/9	7.81**
		-0.26	(undisturbed seedbed)	.62		
		-0.21	(precipitation)	.72		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant at 10-percent level.

Table 39—Regressions between stocking and environmental variables for clearcuts in the white fir type

Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
	Regression formula			Statistical values		
Total	195.91	-0.012	(elevation)	0.56	3/10	17.06***
		+4.06	(aspect)	.64		
		-1.93	(ground cover)	.84		
Advance all species	-85.21	+187.10	(radiation index)	.25	2/11	9.40**
		+0.54	(undisturbed seedbed)	.63		
Advance Douglas-fir	-26.62	+0.37	(undisturbed seedbed)	.43	3/10	25.74***
		+77.41	(radiation index)	.82		
		-0.16	(ground cover)	.89		
Advance true firs	-67.44	+0.48	(undisturbed seedbed)	.37	2/11	21.24***
		+146.10	(radiation index)	.79		
Advance incense-cedar	-56.07	-0.22	(precipitation)	.10	3/10	[2]2.33
		+123.38	(radiation index)	.15		
		+0.74	(aspect)	.41		
Total subsequent	192.48	-0.013	(elevation)	.55	3/10	13.96***
		+3.99	(aspect)	.64		
		-1.83	(ground cover)	.81		
Second-year	-80.07	+153.30	(radiation index)	.16	3/10	8.37**
		+0.15	(woody perennials)	.57		
		+0.002	(elevation)	.72		
Subsequent Douglas-fir	-5.60	+0.16	(woody perennials)	.36	2/11	7.41**
		+0.13	(seed source distance)	.57		
Subsequent true firs	156.96	-306.08	(radiation index)	.25	5/8	4.60*
		+1.13	(undisturbed seedbed)	.39		
		+0.20	(seed source distance)	.49		
		+0.008	(elevation)	.59		
		-0.91	(ground cover)	.74		
Subsequent incense-cedar	-51.78	+0.32	(undisturbed seedbed)	.27	4/9	5.19*
		+129.98	(radiation index)	.34		
		-0.38	(precipitation)	.53		
		+0.09	(woody perennials)	.70		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant near 15-percent level.

Table 40—Prediction equations for subsequent stocking in partial cuts by forest type

Regression formula					Statistical values		
Stocking	=	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
				DOUGLAS-FIR TYPE			
Total		72.06	-0.81	(undisturbed seedbed)	0.35	2/18	7.91**
			+0.73	(precipitation)	.47		
Second-year		45.76	+0.020	(elevation)	.14	4/16	3.07*
			-245.46	(radiation index)	.24		
			-0.39	(true fir seed source)	.34		
			+0.53	(canopy)	.43		
Douglas-fir		40.05	-0.69	(undisturbed seedbed)	.27	2/18	7.74**
			+0.87	(precipitation)	.46		
True firs		-11.55	+3.67	(aspect)	.29	2/18	5.35*
			+0.52	(canopy)	.37		
Incense-cedar		-117.39	+1.52	(precipitation)	.31	3/17	5.67**
			+214.44	(radiation index)	.42		
			-0.59	(logs, wood, bark)	.50		
				WHITE FIR TYPE			
Total		198.08	-0.38	(true fir seed source)	.22	2/26	5.52**
			-268.35	(radiation index)	.30		
Second-year		17.72	-0.32	(Douglas-fir seed source)	.08	2/26	[2]2.84
			+0.55	(canopy)	.18		
Douglas-fir		6.32	+0.34	(Douglas-fir seed source)	.42	1/27	19.64***
True firs		170.36	-290.43	(radiation index)	.15	1/27	4.67*
Incense-cedar		30.46	-0.56	(true fir seed source)	.28	3/25	7.55***
			+1.23	(precipitation)	.37		
			-0.45	(undisturbed seedbed)	.48		
				PINE TYPE			
Total		399.22	-653.65	(radiation index)	.28	3/9	4.26*
			-0.46	(true fir seed source)	.43		
			-0.81	(Douglas-fir seed source)	.59		
Second-year		-420.03	+5.80	(precipitation)	.40	3/9	4.34*
			+4.73	(aspect)	.52		
			+493.62	(radiation index)	.59		
Douglas-fir		-19.69	+1.21	(slope)	.64	3/9	28.88***
			+1.08	(aspect)	.81		
			+0.11	(true fir seed source)	.91		
True firs		217.40	-0.52	(Douglas-fir seed source)	.13	3/9	[2]3.20
			-1023.69	(radiation index)	.22		
			+0.064	(elevation)	.52		
Incense-cedar		528.30	-0.093	(elevation)	.49	3/9	10.58**
			-0.68	(true fir seed source)	.67		
			-2.09	(slope)	.78		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant at the 10-percent level.

Table 41 — Prediction equations for subsequent stocking in clearcuts by forest type

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
			DOUGLAS-FIR TYPE			
Total	197.99	-0.045	(elevation)	0.78	2/10	54.13***
		+3.22	(aspect)	.92		
Second-year	2.68	+0.16	(precipitation)	.20	2/10	[2]2.75
		-0.53	(aspect)	.36		
Douglas-fir	133.43	+1.84	(precipitation)	.79	3/9	34.81***
		-362.91	(radiation index)	.86		
		-0.83	(slope)	.92		
True firs	78.46	+0.94	(undisturbed seedbed)	.70	2/10	18.64***
		-168.23	(radiation index)	.79		
Incense-cedar	62.33	-0.011	(elevation)	.46	3/9	7.81**
		-0.26	(undisturbed seedbed)	.62		
		-0.21	(precipitation)	.72		
			WHITE FIR TYPE			
Total	120.54	-0.019	(elevation)	.55	2/11	9.86**
		+2.04	(aspect)	.64		
Second-year	-27.91	+66.64	(radiation index)	.17	1/12	[2]2.41
Douglas-fir	33.63	+0.15	(seed source distance)	.19	3/10	[2]2.40
		-78.14	(radiation index)	.33		
		+0.23	(undisturbed seedbed)	.42		
True firs	103.97	-231.41	(radiation index)	.25	3/10	[2]3.27
		+0.67	(undisturbed seedbed)	.39		
		+0.19	(seed source distance)	.49		
Incense-cedar	-28.73	+0.34	(undisturbed seedbed)	.27	3/10	3.71*
		+85.43	(radiation index)	.34		
		-0.37	(precipitation)	.53		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant at or near the 10-percent level.

Table 42—Prediction equations for subsequent stocking in partial cuts by geographic area

Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
	Regression formula			Statistical values		
			DEAD INDIAN			
Total	252.51	-0.45	(true fir seed source)	0.27	2/41	13.89***
		-369.49	(radiation index)	.40		
Second-year	-48.94	+1.53	(precipitation)	.16	3/40	5.12**
		+1.73	(aspect)	.20		
		+0.52	(canopy)	.28		
Douglas-fir	7.27	+0.56	(Douglas-fir seed source)	.47	2/41	21.40***
		-0.44	(slope)	.51		
True firs	282.48	-444.41	(radiation index)	.28	2/41	12.37***
		-1.16	(precipitation)	.38		
Incense-cedar	70.35	-0.69	(true fir seed source)	.19	2/41	13.52***
		-0.69	(Douglas-fir seed source)	.40		
			BUTTE FALLS			
Total	104.24	-0.81	(undisturbed seedbed)	.47	1/19	16.80***
Second-year	47.08	-0.34	(Douglas-fir seed source)	.16	1/19	[2]3.49
Douglas-fir	-24.05	-0.49	(undisturbed seedbed)	.22	4/16	5.90**
		+0.65	(Douglas-fir seed source)	.35		
		+0.55	(true fir seed source)	.52		
		+0.86	(precipitation)	.60		
True firs	-11.71	+1.23	(precipitation)	.22	1/19	5.47*
Incense-cedar	42.89	-0.79	(undisturbed seedbed)	.30	3/17	7.03**
		+0.027	(elevation)	.44		
		-1.49	(precipitation)	.55		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant at the 10-percent level.

Table 43—Prediction equations for subsequent stocking in clearcuts by geographic area

Regression formula				Statistical values		
Stocking =	constant	±	environmental variable	Cumulative R^2	Degrees of freedom	F ratio[1]
			DEAD INDIAN			
Total	275.51	-690.83	(radiation index)	0.22	2/13	4.06*
		+3.01	(precipitation)	.38		
Second-year	4.56	-0.77	(aspect)	.15	3/12	[2]2.43
		+0.27	(slope)	.27		
		+0.28	(undisturbed seedbed)	.38		
Douglas-fir	155.23	-309.80	(radiation index)	.16	2/13	[2]3.36
		-1.32	(aspect)	.34		
True firs	413.02	-826.69	(radiation index)	.39	2/13	11.32**
		-3.18	(aspect)	.64		
Incense-cedar	-23.44	-1.25	(precipitation)	.16	4/11	5.04*
		-0.39	(undisturbed seedbed)	.37		
		+0.011	(elevation)	.54		
		+0.07	(seed source distance)	.65		
			BUTTE FALLS			
Total	101.19	-0.012	(elevation)	.65	4/6	28.03***
		+1.50	(aspect)	.84		
		+0.21	(seed source distance)	.89		
		-0.41	(slope)	.95		
Second-year	-48.86	+0.32	(precipitation)	.30	2/8	6.36*
		+86.42	(radiation index)	.61		
Douglas-fir	-64.11	+1.68	(precipitation)	.75	2/8	19.97***
		+1.97	(aspect)	.83		
True firs	-88.97	+0.89	(undisturbed seedbed)	.68	4/6	21.90***
		+0.027	(elevation)	.78		
		+0.35	(seed source distance)	.89		
		-0.47	(slope)	.94		
Incense-cedar	-171.93	+343.47	(radiation index)	.41	3/7	4.79*
		+2.01	(aspect)	.52		
		+0.19	(undisturbed seedbed)	.67		

[1]1 asterisk denotes significance of the regression F ratio at the 5-percent probability level; 2 asterisks, 1-percent; 3, 0.1-percent.

[2]Significant at or near the 10-percent level.

Stein, William I.

1981. Regeneration outlook on BLM lands in the southern Oregon Cascades. USDA For. Serv. Res. Pap. PNW-284, 70 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A survey of cutover timberland in the Butte Falls and Dead Indian areas showed that most partial cuts were moderately or well-stocked with natural regeneration. Clearcuts in the Butte Falls area were also well-stocked, primarily with planted ponderosa pine; but many in the Dead Indian area were not. Advance regeneration was an important stocking component in partial cuts. Stocking varied by forest type, species, and drainage and correlated with an array of environmental variables. Regression equations describe present stocking patterns, and others predict future stocking based on variables that can be observed or specified before harvest.

Keywords: Regeneration (stand), regeneration (natural), regeneration (artificial), clearcutting systems, partial cutting, stand development, Oregon (Cascade Range).

Pacific Northwest Forest and Range
Experiment Station
809 NE Sixth Avenue
Portland, Oregon 97232

GPO 994-596